EXCAVATIONS OF THE PREHISTORIC IRON INDUSTRY IN WEST BORNEO

by Tom Harrisson and Stanley J. O'Connor

Volume I

RAW MATERIALS AND INDUSTRIAL WASTE

DATA PAPER: NUMBER 72
SOUTHEAST ASIA PROGRAM
DEPARTMENT OF ASIAN STUDIES
CORNELL UNIVERSITY, ITHACA, NEW YORK
APRIL, 1969

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Volume One

Raw Materials and Industrial Waste

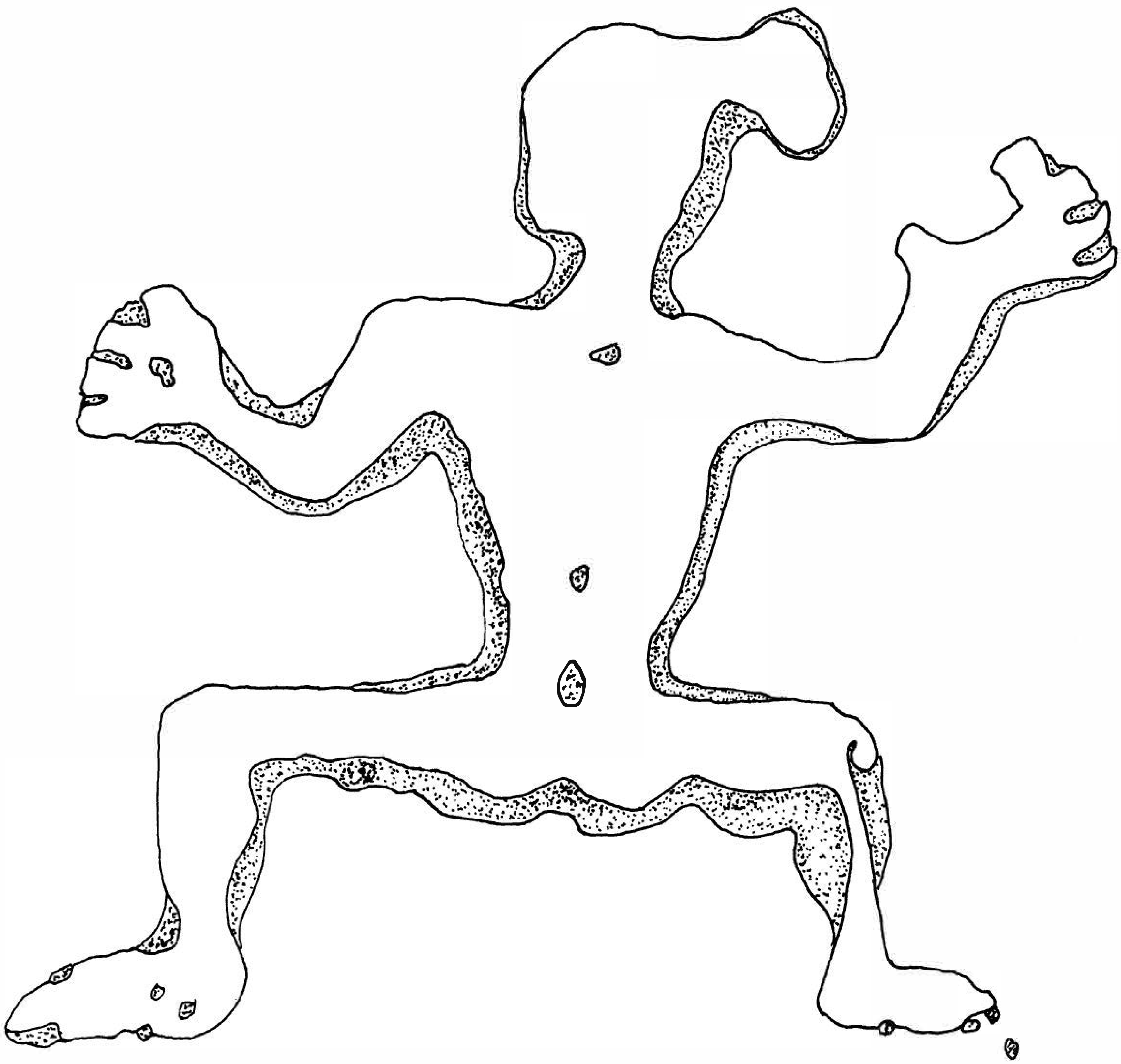

Plate 1. "Batu Gambar." Rock Carving Located at Jaong (Chapter V.32.a).

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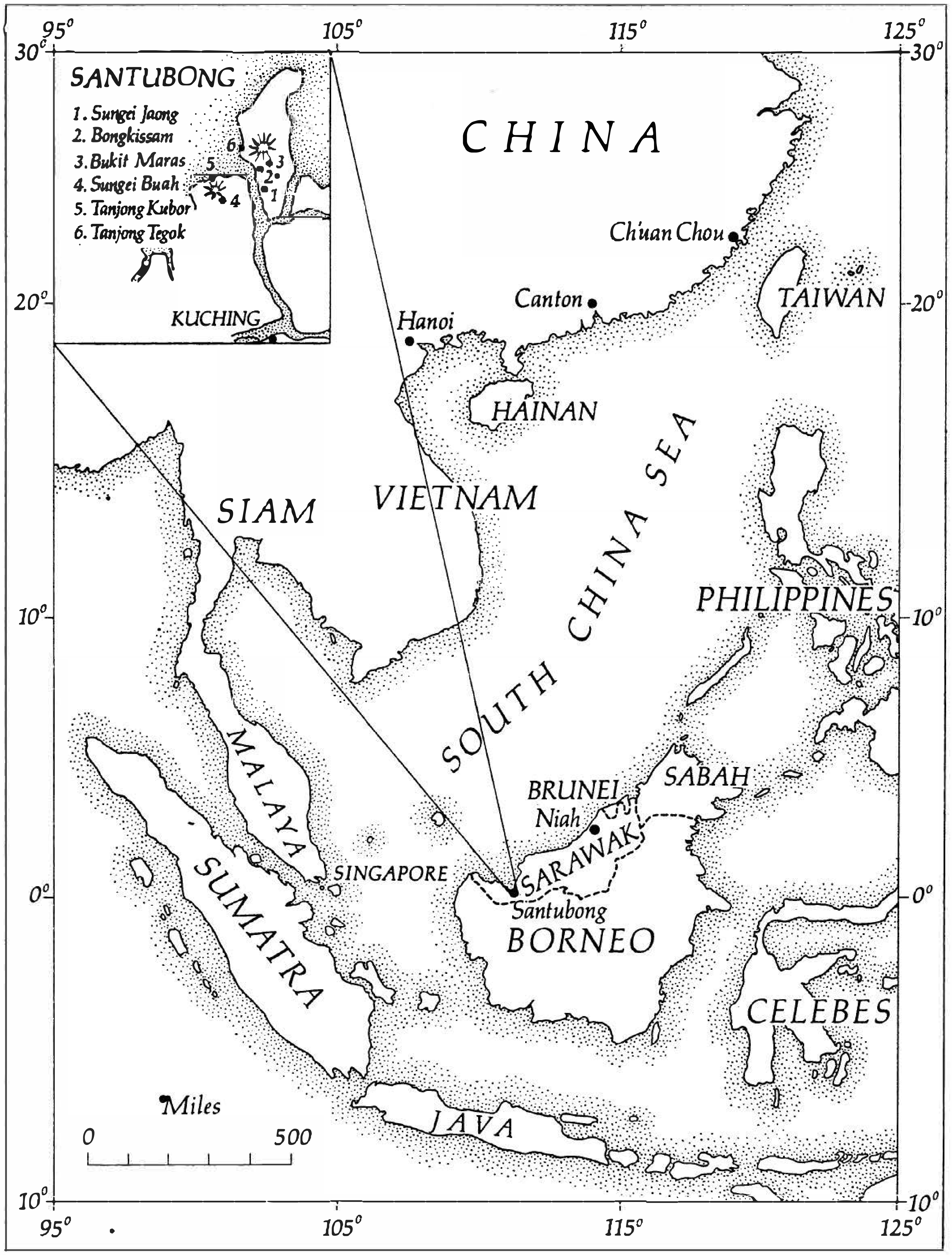

Plate 2. Principal Sites in Santubong Area, after Chêng, *Archaeology in Sarawak*.

"The sail up the (Sarawak) river, our first sight of the country and the people, was indeed exciting, and filled us with delight. The river winds continually, and every new reach has its interest: a village of palm-leaf houses built close to the water, women and children standing on the steps with long bamboo jars . . . boats of all sizes near the houses, fishing-nets hanging up to dry, wicked alligators lying basking on the mud; trees of many varieties--the *nibong* palm which furnishes the posts of the houses, the *nipah* which make their mat walls, and close by the water the light and graceful mangroves, which at night are all alive and glittering with fire-flies."

Harriette McDougall, *Sketches of Our Life in Sarawak,* 1890, p. 15.

"The ground then lies fallow eight or ten years, and becomes covered with banboos and shrubs, which often completely arch over the path and shut out everything from the view. Three hours walking brought us to the village of Senankan, where I was again obliged to remain the whole day, which I agreed to do on the promise of the Orang Kaya that his men should next day take me through two other villages across to Senna, at the head of the Sarawak River. I amused myself as best I could till evening, by walking about the high ground near, to get views of the country and bearings of the chief mountains. There was then another public audience with gifts of rice and eggs, and drinking of rice wine. These Dayaks cultivate a great extent of ground and supply a good deal of rice to Sarawak. They are rich in gongs, brass trays, wire, silver coins, and other articles in which a Dayak's wealth consists; and their women and children are highly ornamented with bead necklaces, shells and brass wire. . n . After crossing the Kayan River, a main branch of the Sadong, we got on to the lower slopes of the Seboran Mountain, and the path lay along a sharp and moderately steep ridge, affording an excellent view of the country. Its features were exactly those of the Himalayas in miniature, as they are described by Dr. Hooker and other travellers; and looked like a natural model of some parts of those vast mountains on a scale of about a tenth, thousands of feet being here represented by hundreds. I now discovered the source of the beautiful pebbles which had so pleased me in the river-bed. The slaty rocks had ceased, and these mountains seemed to consist of a sand-stone conglomerate, which was in some places a mere mass of pebbles cemented together. I might have known that such small streams could not produce such vast quantities of well-rounded pebbles of the very hardest materials. They had evidently been formed in past ages, by the action of some continental stream or seabeach, before the great island of Borneo had risen from the ocean. The existence of such a system of hills and valleys reproducing in miniature all the features of a great mountain region, has an important bearing on the modern theory, that the form of the ground is mainly due to atmospheric rather than to subterranean action."

A. R. Wallace, *The Malay Archipelago,* 1869

PREFACE

The present text is part of a much wider study on the prehistoric open-sites of the Sarawak River delta around Santubong in southwest Borneo. These sites were first seriously noted by H. H. Everett in 1909, first systematically explored and excavated from 1947 onwards by one of us as Curator of the Sarawak Museum (1947-1966). We are now working on a full-length report at Cornell University; the provisional Contents Sheet for this forms Appendix D here, thus enabling the reader to see this particular material in itst more general setting, as the first two in a series of volumes projected. An earlier paper has reported separately on one special feature, a "Tantric Buddhist" shrine with associated gold and other jewelry at Santubong (see Basic References on page xi). For a scholarly andtwell-written general survey of the delta and its importance, there is Dr. Cheng Te-K'un's *Archaeology in Sarawak* (Cambridge, 1968) which in part is based on sections of the draft report loaned to him, although the views he expresses are his own--and tend to lay a greater emphasis on the Chinese role that we might do on the existing information (cf. Appendix A for discussion).

The feature of the delta sites which is least immediately pleasing to the archaeologist, yet in several respects the most significant to an understanding of Southeast Asian pre-history, is the massive evidence of large-scale iron-working starting around a thousand years ago and now lying submerged in the mangrove swamps, rubber gardens and durian orchards of Bongkisam (a part of Santubong village), Sungei Jaong (now a tiny uninhabited creek a mile and a half upstream on the right bank), Sungei Buah (likewise two miles up on the left bank) and elsewhere scattered over an arc of 40-50 miles behind the South China Sea coast on the wide bay of Santubong. This activity in Iron is the subject of the present paper.

In making this presentation we emphasize that this is a Data Paper, in the strict sense of this series. It aims to present the basic data on that part of the Sarawak River delta study which relates to prehistoric iron-working, on the basis of the material available to us at the time of writing. We believe some new points emerge from these data directly. But we are also well aware that the study so far raises about as many questions as it answers--maybe more. The paper is thus a *starting point* for more and much needed further research.

In particular, there is a clear need for more exact and analytical study of the iron slags, ores, local clays, crucible and/or tuyère (nozzles) of clay, including sophisticated laboratory tests, microphotography, X-ray and other examination. These may well require significant revision or extension of the present text. Now that this text is complete and in circulation, such further research becomes practicable.

At the same time, this paper is offered in the hope that it will suggest some research goals and subsidiary methods hitherto perhaps somewhat underestimated in Southeast Asia especially. The tendency has been to ignore some of the problems here discussed, in favor of more tractable and aesthetically attractive aspects, such as stoneware and glass, iconography and epigraphy; and--further back in time --tool and other typologies for the late (neolithic) stone age out of which this iron grew, indeed exploded.

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Ithaca, New York
January 1969

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The above twelve titles will hereafter be referred to by author's name and page only. Thus "Wolters: 32" is page 32 in the last item on the list. Otherwise, the reference is given in brief in the main text with a number (Hartwell: 1964) indicating full reference in the Chapter notes, which follow the main text.

Three periodicals basic for this area are similarly cited in brief in the text where desirable (and likewise in the notes):

F.M.J. = Federation Museum Journal, published after 1950 from Kuala Lumpur; deals with West Malaysia; largely archaeology.

J.M.B.R.A.S. = Journal Malayan (then *Malaysian*) *Branch, Royal Asiatic Society*, important general source for historic and prehistoric papers and monographs.

S.M.J. = Sarawak Museum Journal, defunct 1937, revived 1949; clearing house for papers about Sarawak and Borneo generally.

All other journal publications are given a fuller reference description, as necessary, in the Chapter notes.

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PART I

INTRODUCTION

"Three days after a foreign ship has arrived at these shores, the king and his family, at the head of the court grandees, go on board to enquire concerning the hardships of the journey. The ship's people cover the gangplank with silk brocade, receive them reverently, treat them to all kinds of wine, and distribute among them, according to rank, presents of gold and silver vessels, mats with cloth borders and umbrellas. Then the ship's people have moored and gone on shore, it is customary, before they touch upon the questioning of bartering, for the traders to offer the king daily gifts of Chinese foods and liquors: it is for this reasont that when vessels go to P'o-ni they must take with them one or two good cooks. On the full moon and new moon days they must also attend at the king's leve, and all this for about a month or so, after which they request the king and the grandees of his suite to fix with them the prices of their goods; this being done, drums are beaten, in order to announce to all the people near and far that permission to trade with them has been granted.

"On the day when the vessel is about to sail for home, the king also gives out wine and has a buffalo killed by way of a farewell feast, and makes return gifts of camphor, and foreign cotton cloth, corresponding to the value of the presents received from the ship's people. The ship, however, must wait to sail till the festival in honour of the 'Buddha' on the day of the full moon of the sixth moon is passed, when it may leave the anchorage; for, otherwise, it will meet with bad weather on its journey.

"Their god has no image in human shape; his dwelling consists of a red-covered building of several storeys, shaped like a pagoda; below there is a small shrine protecting two pearls; this is called the 'Sacred Buddha'."

Chao Ju-kua, *Chu fan chih*, earliest known account of Borneo, 1225 A.D. (Hirth and Rockhill trans., 1911).

I.1. DELTA BACKGROUND

(a) General Orientation

The Sarawak River, which subsequently gave its name to the independent country founded by the White Rajah Brookes (and now the largest state in Malaysia), rises in the limestone mountains on the Indonesian border behind Bau, an ancient center for Chinese gold-working. Although less than 60 miles long, it drains a wide hilly hinterland then the coastal plain of poor sandstone soils, reaching the South China Sea as a system of great river mouths, up to 1000 yards wide, with a labyrinthine delta of mangrove and nipah swamp stretching over clayey mud and coraline sand from the most westerly mouth at Sibu Laut, through the big Malay villages of the Santubong, Buntal and Bako mouths for twenty miles to Muara Tebas, now the most easterly exit and the deepest, used by ocean-going steamers (see Plate 2. Map).

The apex of this terrain is the fine peak of Santubong Mountain, 2,658 ft., a natural landfall, overshadowing Santubong village, directly facing out into what is in effect the ocean--with nothing static upon it between Borneo and Indo-China, nearly a thousand miles north. It was up this Santubong mouth that James Brooke first came in 1838, and soon established what is still Sarawak's capital, Kuching, 14 miles up river, to bring his sort of order out of what was at that time near-chaos. Such chaos, indeed, that not only was there no one then living at the present flourishing coastal villages, but there is every indication that no one had done so for a long time past (Harrisson, 1964: 411-413).[1]

(b) Early Reports of Early Remains

In 1848, the Brookes built a seaside hide-out at Santubong. There the co-founder of modern evolutionary thinking, Alfred Russel Wallace, spent two Christmases, 1854 and 1855 (the Sarawak Museum's delta field H.Q. is close to that historic site).

Prehistory was not apparently detected by these earliest outsiders. But when H. H. Everett and Ernest Hose[2] arrived in the last decade of the nineteenth century, the growing local population began to bring in surface finds of beads and gold, which also attracted the attention of these gentlemen's elder brothers, A. H. Everett and Charles Hose, both voracious collectors of and dealers in every sort of Sarawakeana. Although the Sarawak Museum had been well established by this time, curators from 1910 on paid no serious attention to this field for potential study. However, a considerable body of casual information was built up, and was preliminarily reviewed to 1948 (in Harrisson;[3] cf. Everettt and Hewitt, 1909).[4]

(c) Habitation Land

In effect it was necessary to start again from scratch after 1947, however. It was then decided to examine the whole area of the Sarawak River delta and its associated river systems debouching into the great bay between Capes Datu and Po, treating these as one ecological unit. This terrain was therefore surveyed from two main angles: present day, socio-economic life (which is the subject of a volume now in press with Macmillan, London); and prehistorical. This way, a wider perspective was hoped for, looking at the land and its related waters as a whole.

The *habitable* land in the delta is basically old sandstone clays with relatively small amounts of other, harder stone--relevant to iron metallurgy (see V.28 on tools, etc.). The prehistoric sites to be discussed are all on this sandstone clay, secondarily fringed with old coral sea sand or by the massive alluvial sand-clay deposits brought down river with heavy rains.

The soil itself tends to get water-logged. But all delta archaeological sites lie above the present water table and are free of the peat or other soil factors (fairly common elsewhere in such situations) that *help* to preserve wood, bone, and other biological matter--all of which totally vanish under Santubong conditions, unfortunately for the archaeologist.

A series of soil samples from the richest of the sites, Bongkisam, was kindly analyzed by the Department of Agriculture, Sarawak:[5]

Sample Number		Depth	Percent Nitrogen	Percent Carbon	p.p.m.p.
MS 1064	Bongkisam Soil	6-12"	0.089	1.67	565
MS 1065	Bongkisam Soil	12-18"	0.045	1.05	405
MS 1066	Bongkisam Soil	18-24"	0.002	0.48	50
MS 1067	Bongkisam Soil	24-30"	0.027	0.22	25

I.2. SYSTEMATIC EXCAVATIONS, 1947-66

Systematic delta exploration excavation was begun by T.H. (as Curator) in the area in 1948; and extensively in 1952, upriver from Santubong at Sungei Jaong, where a single strange rock-carving of a spread-eagled human figure had long been a landmark on an otherwise unprepossessing swamp creek; and at Bongkisam, part of the present-day Santubong village lying on the upriver side of the bridged creek there.

(a) Slow But Steady Process

Initial results were fruitful. It was soon found that the easiest way of detecting diggable sites was by the presence of metallic iron slag--seldom now showing on the surface, often deep in ground covered with dense vegetation or overlayed with estuarine muda Mine detectors were employed, and large areas of iron-positive ground thus mapped (see IIa5 below)a This slag regularly occurred in association with smaller quantities of clay cylinders (broken); stoneware of types well established as of Chinese manufacture; earthenware (of broadly "native" or local character); glass beads and some bangles similar to those in prehistoric sites in Malaya, Laos and elsewhere, all of uncertain and probably varied "western" (not Chinese) origins but still worn and highly valued by some of the inland peoples of Borneo today; a Gupta-type Buddha and a few Indian itemsa, and pieces of goldaa

Using the iron slag as a general indicator, excavation was extended to cover a wider range of sitesa A large body of material was thus acquired for orderly study in the Sarawak Museum, properly identified by site, trench, depth, date, etc. Not less than 1,000,000 pieces are involved, of which 99.9% are now in Kuching or stored at Santubonga

Little has so far been published on this work. At first, it was difficult to get the Sarawak government or anyone else to see its significancea At that time the literature relating to early Southeast Asian commercial relationships elaborately documented trade sites in Malaya, Java, Sumatra and elsewhere, but in Borneo only Brunei was acknowledged as fairly importanta There was no literature at all on iron-working in this context--indeed, this is the first exercise in this particular field (cfa VIa33). Again, area scholarship has put great emphasis on things like kingfisher feathers and camphor and gold, but virtually none on the base metals. In this intellectual climate it was especially difficult for others to take the initial delta research seriously. Not until John Pope (now Director of the Freer Gallery of Art, Smithsonian Institution, Washington) visited Jaong in 1957 and wrote a strong letter of support to His Excellency the then Governor of Sarawak--at that time a Crown Colony--was even minimal finance and the more important moral backing forthcoming.

At the same time, the Sarawak Museum had also been developing its stone age cave studies, first upriver at Bau Caves; by 1957 more ambitiously far away in Niah Great Cave, which soon engaged most of the available attention, and more ready finance and specialist help. Work at Santubong and more widely along the coast continued as and when opportunity permitted into the sixties; but it had to take second place after 1959. No outside funds were expended on *any* of this coastal work until 1966.

(b) 1966 Special Studies

By 1966 it had become urgent to fill in the delta gaps. The Curator (T.H.) was due to retire in September, and felt that his experience and planning on the work might be lost if not rounded off. He therefore invited the co-author (S.O'C.) to participate fully in further specialized operations; this visit, during June and July 1966, was made possible through the support of the John D. Rockefeller III Fund. This paper is the first general account of one aspect of the results obtained over the whole period. It is hoped that it may prove to be only one in a series based on a continuing co-operation.

At the end of 1965 an analysis was made of what seemed the outstanding problems of the delta sites which required further close examination. Some, such as the headland cemeteries, held no remaining problems likely to be settled by further excavation. Particular small sectors of four other large sites were chosen for specific studies at a few spots, sometimes in narrow, finely layered trenches, sometimes with larger trenches and less elaborate layering. Most of these were aimed at further elucidation of the biggest and more difficult aspects of the delta: the iron industry.

The main content of the present paper will be based on the whole period of these studies after 1947, and this work will constantly be cited. But at some points it will be convenient to concentrate on the more limited 1966 trenches, focused down to bring the earlier work into close-up. These trenches are therefore listed below, for easy reference. The sites numbers are explained in the next chapter (I.3).

Delta Special Trenches, 1966[3]

Site	Trench	Length	Width	Depth	Square Feet	Cubic Feet	Date of Dig
Jaong	X/1	5'	0' 6"	48"	2.5	10.0	15-6
	X/2	5'	0' 6"	48"	2.5	10.0	15-6
	X/3	5'	0' 6"	48"	2.5	10.0	16-6
	M/1	5'	0' 6"	48"	2.5	10.0	20-6
	M/2	5'	0' 6"	48"	2.5	10.0	20-6
	Y/1	5'	5'	48"	25.0	100.0	22-6
	Y/2	5'	5'	48"	25.0	100.0	24-6
	Y/3	5'	5'	36"	25.0	75.0	24-6
	A/1	5'	5'	24"	25.0	50.0	25-6
	A/2	5'	5'	21"	25.0	43.75	6-7
	A/3	5'	5'	21"	25.0	43.75	7-7
	A/4	5'	5'	21"	25.0	43.75	7-7
	A/5	5'	5'	18"	25.0	37.5	8-7
	A/6	7½'	5'	18"	37.5	56.25	8-7
	A/7	15'	4' 6"	18"	67.5	101.25	8-7
	A/8	15'	3' 3"	21"	48.7	85.225	11-7
Jaong Total 16				to 48"	366.2	786.475	
Buah	W/1	5'	0' 6"	84"	2.5	17.5	28-6
	W/2	5'	0' 6"	84"	2.5	17.5	29-6
	W/3	5'	5'	72"	25.0	150.0	30-6
	E/1	10'	5'	30"	50.0	125.0	3-7
	E/2	10'	5'	30"	50.0	125.0	5-7
Buah Total 5				to 84"	130.0	435.0	
Bongkisam							
	Z/1	5'	2'	30"	10.0	25.0	12-7
	Z/2	5'	2'	24"	10.0	20.0	12-7
	Z/3	5'	2'	27"	10.0	22.5	12-7
	Z/4	5'	2'	30"	10.0	25.0	12-7
	Z/5	5'	2'	36"	10.0	30.0	13-7
	Z/6	5'	2'	30"	10.0	25.0	14-7
	Z/1A	10'	3' 6"	30"	35.0	87.5	14-7
	Z/1B	10'	5'	30"	50.0	125.0	15-7
	Z/1C	5'	5'	24"	25.0	50.0	17-7
	Z/1D	5'	3'	24"	15.0	30.0	17-7
Bongkisam Total 10				to 36"	185.0	440.0	

Site	Trench	Length	Width	Depth	Square Feet	Cubic Feet	Date of Dig
Bukit Maras							
	I	5'	3'	24"	15.0	30.0	18-7
	I/2	5'	3'	24"	15.0	30.0	18-7
	I/3	10'	3'	18"	30.0	45.0	18-7
	JB	15'	5'	24"	75.0	150.0	19-7
	A	15'	3'	30"	45.0	112.5	20-7
	A/2	10'	5'	30"	50.0	125.0	21-7
Bukit Maras Total 6				to 30"	230.0	492.5	
Ayer	W/A	10'	5'	18"	50.0	75.0	20-7
	W/B	5'	5'	18"	25.0	37.5	20-7
	W/C	5'	5'	18"	25.0	37.5	21-7
	W/D	5'	5'	18"	25.0	37.5	22-7
Ayer Total 4				to 18"	125.0	187.5	

I.3. KEY SITES AND MOBILITY

(a) The Range of Delta Sites

Many archaeologically positive sites have been found and proved by test excavation in the Sarawak River delta along the lines previously outlined. Five have been extensively studied. Of these, three--Sungei Jaong, Sungei Buah, and Bongkisam (Sungei means stream or creek)t--are rich in iron slag and associated clay cylinders, along with trade goods not directly connected with smelting metal. There are only a few sites where smelting *alone* appears to have taken place; these are always small and usually superficial.

This paper pays special attention to the *three large sites*, adding from others as necessary, including one examined for the first time in 1966, Kampong Ayer. A full report on the *non*-smelting burial ground at Tanjong Kubor has already been published, showing that it was used over a short period (perhaps only a century) before 900 A.D. This and *all other* sites not discussed in the present paper are nevertheless parts of one related operation stretching over several centuries (see b-d below) and firmly centered on the working of iron ores.

It needs to be emphasized that the scale of these iron and related operations really was very large. The material already recovered and housed in the Reference Collections of the Sarawak Museum was already so great that in June 1966 when S.O'C. arrived in Kuching and saw only a part of it (most is in store), he exclaimed:

"It has to be seen to be *believed*!"

But all that we have recovered is the refuse, the rejects, the rubbish, the detritus of a vanishedtcommerce in consumer goods: the silenced echo of a mighty past. Without doubt there is much much more in the ground than has been taken out of it since 1947, though to remove it would be repetitious. Much more, again, has vanished in estuarine erosion, swamp growth, and deeply silting mud.

(b) Key Sites for Iron-Working

First, a brief general account of the three key sites which will be regularly considered hereaftert[1]

(i) *Sungei Jaong* (hereafter Jaong): the name for a series of small creeks on the true right bank of the Sarawak River between one and two miles above the present village of Santubong, examined in 1947, excavated from 1952. Here refers to the lowest downriver of these, which runs for half a mile through nipah palm and mangrove swamp until it touches "dry land" at the southeast slope of Santubong Mt. This creek is only navigable in a small boat (*sampan* or flat-bottomed speed boat) at and around high tide, which comes twice in 24 hours here. At low tide the creek can barely be negotiated by a crayfish; it is mud. The slag and related prehistoric remains stretch for nearly a mile on the edge of the swamp, and small pockets continue much further right through to and along Bako Bay, on the other side of the narrow isthmus which the Jaong creek almost severs (it is possible to pull a small boat across on spring tides).

As can be seen from the air, the Jaong was once a major trench of the Sarawak River system, since wholly silted up--just as the present Santubong mouth has heavily silted and changed since the Brooke advent 120 years ago. To pursue this lies outside our present provenance; but it is painfully made clear to anyone trying to work in this place that no sort of vessel could have brought even a minute fraction of the present reject debris, which is very large--let alone the original trade content and manufactory--to Jaong within human memory or local tradition.

Most of the *excavated* gold has come from Jaong. This gold (V.29) is regularly associated with fine, small ceramic pots, boxes, and bowls recovered whole deep in this deposit, and these latter have been the subject of discussion elsewhere (Harrisson, 1954[2]).

Jaong is characterized, also, by an extensive system of rock-carvings of unknown significance but *related* to the trade activities, iron slag, gold, ceramics (see V.31 following).

There is no contemporary human habitation at Jaong. Most of the land is poor and sandy, except where the slag and other deposits make a rich soil just along the creek, on which durian and other fruit trees grow, mixed with dense jungle (kept clear, 1952-66).

(ii) *Sungei Buah* (hereafter Buah): slightly upriver from Jaong and on the other bank of the Sarawak River, largely excavated from 1955. This is a slightly larger creek (12-15 yards wide at mouth, 2 yards further up) which runs for half a mile to the foot of Bukit Buah, 1200 ft. high, covered with durian and other fruit trees, coconuts and some rubber in places. The main occupation site is on the edge of the coconuts and among durian, and includes the deepest iron slag deposits so far found (to 10 ft.), what appears to be a small "cemetery" section further in, and other deposit indications--followed with spaced sampling trenches--widely elsewhere along the land side of the Buah hill foot.

Here, again, the main river clearly once swept the foot of Buah hill, now separated from all tide water by 300-800 yards of mangrove swampt

The present land-holders with rubber and fruit trees behind the creek can trace back five generations there, and there is some knowledge among them of a longer past, including a belief that a group of Bugis from the Celebes were once in the vicinity and also a vague idea of the sometime presence of Hindus--though this was not specifically attached to the iron slag or other ground materials before excavation began (cf. also V.29.b).

(iii) *Bongkisam*: just across the bridge over the creek from the Santubong mosque and modern Mohammedan cemetery, and downriver from Jaong on the same bank excavated from 1955. Here one can see from the ground how the river once cut back; a considerable mud flat is left which is filled at high tide. It is apparent that the silt-up here has been later or less complete; and this corresponds with the presence of some ceramic and other items attributable to a rather later date, though basically Bongkisam parallels Buah in the general run of material (cf. I.4 following).

Iron slag does not occur here quite in such *dense* concentrations as at Buah and parts of Jaong, but is scattered over a notably wide area, including for over half a mile inland along the present right bank of the river, through fruit and rubber gardens.

Through the courtesy of A. K. Merican Salleh, the Museum was able to excavate one very large unbroken sector here (II,JJ), destroying a quarter of an acre of rubber in the process.

It was at Bongkisam that H. H. Everett made his home and the fifth largest rubber garden in Sarawak (Harrisson,t 1964: 427), and from this that most of the casual finds have come, as noted above.

The provisional count of the total finds catalogued for the 1955 season (only) gives some idea of the nature of artifacts in the ground here:

Ceramics, etc.:	67,668	Earthenware sherds
	49,393	Stoneware and Porcelain
	659	Glass (Beads and Bangles)
Metal:	84	various (excluding slag)t
	3,107	crucible pieces

(c) Topographical Factors Summarized: Access

Bongkisam, on the edge of Santubong village, is the most accessible of the three major iron sites. The other two are out of the way by normal standards today, and were much more so before the Sarawak Museum opened up overland paths and cleared the creekways through the dense mangrove and nipah palm swamp. These present-day situations result from extensive silting and river change, as can be easily seen from the air, elaborated by a long series of aerial photographs arranged especially for us by the Director of Lands and Surveys, Sarawak. The Sarawak River has continued to meander, closing old and opening new courses, even into historic times.

What made Jaong, Buah, and Bongkisam, now literally backwaters to man, attractive as smelting centers long ago? The following summarizes the situation for *all three*:

1. An adequate supply of fresh water from the hillt
2. Feeding into a branch of the big river, forming ready access to mangrove wood for fuel, estuarine clay for pot-making, and the carriage of ores.
3. Shelter from the open sea and the monsoon-swept estuary.
4. Plenty of flat, sandy-soil land for operations close to the water.

5. Drier, sloping land for habitation and cultivation behind, the whole accessible by a short sail to the sea.
6. Or by sail and paddle back upriver for long distances (with much tide assistance).

The actual presence of iron was not, apparently, relevant. There is no sign of on the spot mining attempts. The ore-bearing material was brought in by boat (IV.20-24).

Other local factors may well have operated beyond our present capacity to recapture. The most likely of these are religious, spiritual, superstitious considerations which could greatly influence the *choice* of sites for this sort of operation, both in ancient and recent times on Borneo.[4]

A broader topographical factor is the position of the Santubong sites in relation to the hinterland and to the South China Sea. In relation to the South China Sea, Santubong Mountain has already been noted as rising 2900 feet in a striking, beautiful domed landfall at the end of hundreds of miles of open coastline with the hills much further back. The great bay which arcs across from the high headland westward to Tanjong Datu forms a natural terminal before you turn the corner to the island's south coast. This character is meaningfully recognized by the modern political boundary between Indonesian Kalimantan and Malaysian Sarawak, which runs out to the coast on Tanjong Datu. In the days before the compass became available as a navigational aid over open sea--in the twelfth century--the arrangement of coastal features, especially in relation to the monsoons sweeping the coast, was much more important than it is today, when steam has also overcome the handicaps of sail in these difficult waters.

In relation to the hinterland, the Sarawak River drains out through several mouths at Sibu Laut, Santubong, Buntal, Baku, and Muara Tebas, from a wide section of hill country, sandstone and limestone, now (and probably far back) one of the most densely populated rural areas in the island. The river is exceptionally easy for small-craft, by Borneo standards, and reaches large population areas in a journey of a day or less, compared to the long, narrow habitation zones which characterize the West Borneo valley systems. The Bau sector of the headwaters has been a major world source of gold into this century and the area has a strong metal tradition. The first regular European exploitation was in this area for antimony, which attracted the first White Rajah 120 years ago. He recognized the special character of this river system by making his home at Kuching near the tidal limits, up from Santubong. There, by wise manipulation of co-operative native peoples he chiseled out a new country in Asia, named after the river. Kuching remains, of course, the capital of Sarawak in Malaysia.

As well as on the hinterland directly drained by the Sarawak River, adjacent headwaters of other big rivers are divided by only low watersheds--including the whole drainage system *southward* towards the Java Sea, through what is now Indonesian Kalimantan. There is no significant physical barrier between the heads of the rivers flowing either way across Borneo in this section. In consequence, there is a traditional flow of related persons, of land commerce freely from the hinterland of the south coast northward and westward into the Sarawak River; in historic times this has been important in linking diamond and gold areas of Kalimantan along with the very old Chinese settlement at Montrado in that hinterland (cf. Harrisson).

The presence of a "cooperative" people resident in numbers is the last general factor which need be stated here. This can only have been of great assistance in establishing large-scale operations down in the delta, which depended on indigenous aid, active and extensive. Without such co-operation, the operations here discovered and discussed would seem quite impracticable.

(d) Other Delta Sites Less Relevant Here

Brief note must be taken of other explored and excavated delta sites which though not here taken as primarily relevant for the study of our present theme, iron-working, nevertheless are all part of the same complex, and must be mentioned in passing in any discussion of delta matters.

(i) *Kampong Ayer* (hereafter Ayer): test trenches from 1952, some additional special study in 1966 (see II.8.h). This is on the single foot-track through old rubber and scrub from Bongkisam to Jaong close to the swamp edge by the main river. It was for a time inhabited by H. H. Everett's workers early in this century and probably some of the pre-1947 "finds" were here. The whole sector has continuing slag and other deposits, though outside the main "concentrations." No surface sign of habitation now remains.

(ii) *Bukit Maras*: the hillside above Bongkisam, thickly rubber planted; long series of small spaced single trenches from 1952 and 1966, but no chance of larger site operations without buying the land. Slag present but erratic on the hill, in a primarily habitation area, contemporary with Bongkisam but without the great trade debris. For instance, the 1955 trenches gave a very low number of import stonewares and numerous preponderance of "native" prehistoric earthenwares:

40	stoneware sherds
85,582	earthenware sherds
508	glass (mostly beads)
152	metal (*none* gold)

Slag does run up to 200 feet above the river level, but it is not a primary working area.t

(iii) *Muara Tebas*: a Malay village at the most easterly mouth of the delta system, now the steamship source out from Kuching. Excavated in 1952, and slag proved over a considerable area around and in the present village at the foot of the Chinese temple-hill alongside. Crucible also present in quantity, along with the usual stonewares and some earthenware. Contemporary broadly with Bongkisam, which is 6-8 hours away by sail--either upriver and down again inland, or along the coast and round Santubong Mountaint

(iv) *Telok Serabang*: on Tanjong Datu, at the opposite, east side of the bay structure from Muara Tebas, a good day's sail away. Explored from 1947, and planned for 1966 excavation--but population had to be evacuated because of Indonesian fears during "Confrontation," as it is close to the border of Malaysia and Indonesia. The small hillock behind this delta bay is rich in slag and associated "crucible,t' with Chinese stonewares, etc.

(v) *Sematane* on the Santubong (westward) side of Telok Serabang; a number of slag sites located up the Sematan River on creeks of Sarawak River type, but with smaller scale deposits. Whole area majorly disturbed by bauxite mining since 1956.

(vi) *Temakal*: deep in the swamp near the Malay village of Sibu Laut on the western side of the delta, in some of the densest mangrove areas; a mound of prehistoric slag associated with the village's (recent) Moslem cemetery--so that it could not be excavated without giving offense (see also II.8.a).

The above six sites all carry iron-slag, often in large amounts (III.6.a). The following four--and others too small or too little studied to rate a mention here--have little slag and no associated "crucible," though rich in Chinese stonewares and local earthenwares and other artifacts. All are regarded as cemeteries, contemporary with the iron working:

(vii) *Tanjong Kubor*: a headland (*Tanjong*) on the seaward side of the Buah hill, completely excavated in 1955 fully reported upon (T. and B. Harrisson, 1957; W. S. Solheim, 1965).[5] In use between seventh and tenth centuries A.D., but probably for only part of that time. 33,000 artifacts.

(viii) *Tanjong Tegok*: a much smaller headland 1½ miles from Kubor on the Santubong side of the estuary. Fully excavated in 1956, but not yet published, less than 2,000 artifacts.

(ix) *Pulau Kra*: a tiny islet (*pulau*) 700 yards off Kubor headland. Many stoneware sherds wash up on small beach; burial pots among rocks and roots. Searched, 1954-65.

(x) *Bako*: a small rocky-topped hillock above a big Malay village in the center of the delta complex, between Santubong and Muara Tebas, with some early Chinese stonewares. Fully searched, 1957-59 (not possible for excavation).

This scatter of sites will perhaps give some background "feel" to the quantity, quality and diversity of activity connected with the three main iron-working sectors, Jaong, Buah, Bongkisam. A whole coastline, its bays, estuaries, anchorages, creeks became involved in this traffic of export, which reached back up the big river into the hinterland--where many more slag sites have been located, too.[6]

I.4. TIME SEQUENCE IN THE DELTA

(a) Difficulties in Laboratory Dating

Until very recently, material dateable by modern radiocarbon half-life and other methods has not been satisfactorily available from the delta sites. It should be here emphasized that although some of the human deposit, notably at Buah, runs feet thick, nowhere is it significantly stratified in a *series* of occupations, giving measurable levels of distinct periods in the ground. There are two main reasons for thist

(i) The center of activity evidently shifting from one place to another, partly because of land changes and especially the silting up of the creeks and accessibility to materials (including the easy availability of firewood)t The tendency was for intensive use of one site, then a shift--and no doubt we do not have all the links in this chain of movement, some of which are now buried entirely in water or mud.

(ii) Where occupation lasted any considerable length of time, the nature of the iron-working itself chewed up (as we shall see) the whole terrain, cutting through contemporary or previous deposits to produce a highly "confused" artifactual pattern (III.14, V.28-31, etc.).

Thus any artifact at any specific depth in the deposit is unlikely to have been left there and then overlaid in the usual way, by the processes of time. What was the bottom may now be at the top, and vice versa. This difficulty is compounded by further displacement due to agricultural and orchard activity in the past century, and especially rubber planting initiated by Everett and his associates about 1910t Only in parts of Jaong was the place left to revert to jungle after the iron-workers left; and then the root factor was disturbing too. A typical extract from Jaong field notes for the first serious dig there, in 1952, shows how tedious even jungle disturbance can be too:

> In the extensive digging out and clearing of the carved rocks and shaped stones the difficulty presented by trees and tree roots was considerable. Large trees grew directly upon large rocks which had to be clearedt-and subsequently showed human activity. Felling the trees still impeded the work until cleared: some of the

trees were over 100 feet high. Their roots pervaded the area and had to be moved; toppled, upended and split rocks. In some cases roots were found which had grown into and widened cracks in boulders prior to splitting them. Trying to visualise the original positions and shapes of large objects was a corresponding amount of headache. (T.H., 5/52: 43)

(b) C-14 Date (A.D. 1315)

A new method of dating direct from iron has now been worked out at Yale. It is hoped to apply this to delta slag when fully developed. Meanwhile, we have one carbon sample from Bongkisam, Z/3, 9-12", 12.7.66, where there was an unusual concentration of *charcoal* in one small pocket--much mixed with other material (cf. III.18)--in a not especially disturbed section, but one of high interest as a clue to the adjacent Tantric Shrine (V.30). Charcoal is the best available material for testing by accepted methods, and this sample was analyzed by Geochron Laboratories at Cambridge, Massachusetts, in 1968, with the following result:

A.D. 1315

--- with ± 95 years margin of error;
= { 1220 A.D. earliest possible;
1410 A.D. latest possible.

The date could well be a little earlier; it is extremely unlikely to be near the 1410 A.D. limit upward (for reasons and details see III.18). If we take 1300 A.D. as a good round figure for the time being, we are not likely to be far out of time. This is the *first* such laboratory date for any iron-working site in Southeast Asia; and it fits well into the sequences built up over the past two decades on the basis of the ceramic and other typologies already described.

(c) Dating by Association

Fortunately there are other if less exact means to assist in date reconstruction: (i) the great quantity of known types of Chinese stoneware sherds, (ii) occasional Chinese coins, (iii) the rare figures or related objects of Buddhism (found only at Bongkisam of the three main iron-working sites). Much research has been carried out on the stonewares at the Sarawak Museum, and a classification of these wares put forward at the Manila Trade Pottery Seminar in March 1968 (Zainie and Harrisson, 1967).[1] The main conclusions were very fully set out there. This basis has not been challenged, and may be briefly stated as essential dating information here--we shall return to the *relation* between the stoneware trade and iron-working as a whole in Part V.

(i) Stoneware Types and Dates

Nearly all the stonewares excavated in the delta are certainly of Chinese origin; a very few may be Indo-Chinese. All were made during the period T'ang-Sung-Yuan. Some are probably early T'ang, but the great part range from early Sung (i.e., 960 A.D.). The period covered is thus seventh to mid-fourteenth century. Not one sherd has been excavated that could be reasonably regarded as "Ming"--i.e., later than *ca.* 1370 A.D.

There are significant and consistent differences in sherd types between sites. In short, Jaong is rich in earlier wares, such as Yuehttypes, but lacking in, for instance, the well known Sung celadons. Bongkisam and Buah are both rich in these celadons and other wares known to be Sung or Yuan.

(ii) Chinese Coins[2]

Very few coins have been recovered in the two decades of excavations. All are T'ang or Sung--the earliest 618 A.D. (Tanjong Kubor)t. Everett was more fortunate in the treasure hunt days at the turn of the century, and in 1909 reported he had acquired "quite a collection of coins" from around Santubong. Alas, no trace of this or any other such collection remains today, while his account of the finds (1909: 11) is tantalizingly inadequate. All his coins dated from 618 to 1101 A.D., the "commonest" between 976 and 984 A.D. There were then no coins until fully historic times; that is, a big gap from 1101 A.D. possibly indicating a secondary break in direct contact with China about the start of the Southern Sung (1127 A.D.?).

Chinese coins were once widely used in the islands, however, and do not necessarily imply the presence of Chinese populations. Old coins often continued into much later use. But the coin evidence is consistent with the stoneware datewise. It adds up to small but significant support for the general T'ang-Sung time pattern, in this case without Yuan (1280-1368 A.D.).

(iii) Buddhist Materials

Using the term "Buddhist" quite loosely, we have several items, including a stone "Gupta" buddha from Bukit Maras, just above Bongkisam, dated before 1,000 A.D.[3] and the Bongkisam "shrine," which we have put after 1000 A.D. but before 1300 A.D. (cf. V.30). All these materials conform to the stoneware date limits.

(d) The Time Scale for Iron-Working

From the largely indirect but cumulatively powerful sources above described, it is safe to summarize the delta sites, in so far as they concern iron-working, thus:

Start of *iron*-working:	"T'ang dynasty" at Sungei Jaong.
End of *iron*-working:	late Yuan: definitely pre-Ming.

The whole iron operation at all these delta sites can provisionally be fitted into a time span of:

Maximum:	615 to 1370 A.D.
Minimum:	900 to 1350 A.D.
Optimum peak:	*ca.* 1100 to *ca.* 1345 A.D.?

Of the three major slag sites, Jaong is the earliest; Buah and Bongkisam follow Jaong, which was totally abandoned (silted up); Bongkisam continues rather later, after the close down of Buah (also silted). Then, suddenly, it ALL came to an end--before 1380 A.D.

These conclusions are tentative and subject to wide revision. But they are adequate for this Data Paper, which will now concern itself *entirely* with the iron-working remains, as reflected in the slag (II), "crucible" and other clay and related usages (III), metal content and mineral factors (IV), then artifacts directly associated with these iron-workings (V), directly drawing on wider ideas which may arise from this somewhat pedestrian but basically factual data approach (VI).[4]

PART II

THE EVIDENCE OF IRON SLAG

"No country has so far produced so many or such varied iron bars as Britain. Nevertheless, there are continental finds which provide instructiveaanalogies."

Derek Allen in *Proc. Prehistoric Soc.e*, XXXIII, 1967.

"He that hath many irons in the fire, some will cool."

John Ray, *English Proverbæs*, 1670 A.D.

II.5. THE SLAG IN LOCAL BELIEF AND PREHISTORIC FACT

(a) Fossil Faeces

The outstanding characteristic of the Sarawak River delta sites, as compared with any others yet accurately reported in Southeast Asia, is the presence of quantities--often large quantities--of iron slag. This slag is such a feature of the landscape that it is known to the local people as *tai besi*, "iron faeces." It is not thought of as modern or fully natural, but as something from the ancient past--in the same category as petrification, charm-stones, etc. No specific folklore attaches to it, however. One elderly Malay back in 1948 thought it must have been caused by some sort of special celestial outpouring in ancient times, comparable to the upland Kelabit idea linking hailstorms with strangely shaped or positioned boulders (which are thought to be dwellings, people, domestic animals petrified by the hail).

Current explanations are colored today by the results of the excavations over the past two decades. There is now appreciable local knowledge of iron slag in relation to the proven past. No such ideas existed when this project started twenty-five years ago. The slag was not connected with deliberate human activity or frequentation; now was it correlated with the ancient potsherds and other pieces, in some places (notably Bongkisam) exposed at the surface after heavy rain. There was (then) no general belief that there had been a past and extensive population here, let alone that it had anything to do with iron in the utility sense. There were vague traditions of an earlier settlement at Sungei Buah, but no belief in communities at any of the delta villages before the Rajah Brookes brought a new order to the coastal zone after 1838.

No present known source of workable "commercial" iron exists in West Borneo, though inland until very recent times native groups mined, smelted, and worked rock ore for their own purposes--such as the superb Kayan and Kenyah parangs (see VI.37). Laterite, limonite, haematite, and other low-grade ferrous ore-stone occurs widely throughout this part of Borneo, notably around Bau, past center of gold and antimony working at the head of the Sarawak River, 35 miles up from Santubong (cf. IV.20-22).

As we shall see, there is no evidence that any of the slag to be found over many acres around Bongkisam, for a mile along Jaong creek and on the other side of the river for another mile at Buah (in places to 7 ft. depth and more there), as well as in many lesser sites of the delta--dates later than 1370 A.D. (at the latest; I.4). The iron activity and the related barter trade were quite sharply terminated. This "Ming Gap" provides the main reason why the modern population of delta know (or knew) nothing and deduced nothing from the sometimes conspicuous slag indications--e.g., it can be so dense as to make rubber planting and other cultivation quite awkward down at the roots.

(b) Some Less Easy Answers?

It follows that we cannot expect any contemporary or even historical clues to assist in interpreting this massive slag material. Its physical presence is now the reverse of a mystery. But why it is so widely scattered on the surface and at places so dense in depth remains far from obvious, open to numerous uncertainties. The clear initial indication is that the slag is the residue of extensive *iron-working on the spot*. But upon excavation less easy questions immediately arise:

(i) How did the slag pieces get so widely surface-spread; and in massive depth too?

(ii) Why is there relatively little evidence of distinct kilns, ovens, fire points, etc.--despite the presence of much earthenware and burned clay, also charcoal, intermixed with the slag?

(iii) What (if anything) was made?--and why do we find so few "wasters"?

(iv) Where did the ore come from--none is now available in the *immediate* vicinity?

(v) Following from (iv), why was ore brought to and worked *here*, on this spot; since then an almost forgotten corner of Borneo?

These are some of the matters this Data Paper seeks to illuminate, in this and the next two sections. The main immediate difficulty in assessing the significance of the slag in all its implications derives from the way it was worked. The methods of treatment are indicated as fairly simple in style, but complex in associations, suggesting modifications of technology to suit local conditions rather than a "sophisticated" factory of mainland type. This we shall presently pursue, too.[1]

But initially is also seemed *possible* that this great debris of slag and crucible did *not* really or wholly represent simply a local industry, any more than the associated debris of high quality import stonewares and glass represents local manufacture of such refined wares--which were never made in Borneo. The first need then is to examine the general distribution, quantity and character of the slag itself and how it enables us to understand this irontworking, in order to clear the way for further considerations as to local provenance and purpose--as against the possibility of its resulting from dumping (e.g., as ballast) or (as one well-known visiting archaeologist shrewdly suggested) as a by-product from extracting gold--which, in fact, requires no such intense refinement (V.29).

(c) What Slag Is in the Delta

Slag is normally the refuse left over from the smelting process. It can, on a smaller scale, be a residue of a crucible refining process (fully discussed in III.13), or, on a smaller scale still--in the Borneo context--of the final stage in tool-making, the craft of the blacksmith. R. F. Tylecote has well remarked (192): "*How to differentiate smelting and smithing sites is a difficult problem.*" The more the slag, the stronger the indication of smelting, under most circumstances.

Slag, whatever the source, consists largely of silicates, resulting mainly from silica combining under heat with the metallic oxides not useful to the end product--in this delta case, the end product of iron. The compounds passed off in the slag have lower melting points than the iron, and the basis of smelting is the division of these from the required ferrous oxides (less often, carbonates) with the use of carbon monoxide from the fuel (charcoal, etc.; cft III.18) in combustion with injected air:

$$F_2O_3 + 3\ CO \longrightarrow 2\ Fe\ (\text{iron}) + 3\ CO_2$$

This slag is essentially the product of a first process, by heating the raw ore as obtained from the ground. These ores are discussed in Part IV of this paper (and in Appendix C). We cannot *start* with them, because none have been recovered intact in the excavations and we are as yet far from sure even of their exact source(s). The slag is the strong, clear, indeed almost overwhelming evidence of the iron activity in the delta, with crucible a second and, in some ways, more difficult clue. As H. H. Coghlan (42) has remarked:

> As the refuse or slag from an iron smelting furnace is practically indestructible, the examination of such slag is useful in various ways. First, it often leads to the discovery of the smelting site, which could otherwise possibly never be found.

Under tropical conditions such a "lead" is even more valuable. This is the first attempt to treat it as seriously as it deserves in Southeast Asia--where knowledge of the advent of iron remains, outside China and parts of India, deeply inadequate compared with Europe.

The smelting which produces the slag is, then, application of heat to melt the iron out of the ore, ridding it of the useless other minerals. Apart from any possible pre-treatment by roasting, this requires some sort of fire hearth, oven, or kiln, in which to get the ore to the required high temperature. The end of this process is normally, in the simpler techniques, to produce a "bloom" in which "iron," slag, and probably some cinder are mixed, but differentiated. This bloom is commonly pasty, and can be hammered out to separate the slag--maybe repeatedly, with heavy hammers such as the "waisted-stones" found in all delta sites (V.28). It may have to be re-heated several times for further differentiation. Other slag may be tapped off the hearth in various ways.

The end product of this process is "wrought iron," which has a low carbonate content (less than 0.25%) and can be further worked especially by aid of crucibles of clay, without too much difficulty into a malleable steel. The alternative, developed for iron in China--and long China's world monopoly--was to smelt in an enclosed blast furnace (without direct fuel and air contact), usually with coal to keep up the temperature. This produced liquid iron, easily formed, but with a low carbonate content, not malleable but *brittle*--and thus less immediately suitable for making utility-tools, fine cutting edges, and those artifacts which were a priority requirement in Southeast Asia at that time. The Chinese of course elaborated ways to produce a whole range of iron products but casting remained their basic approach (Needham: 13).

II.6a SCALE OF DELTA IRON DEPOSITS: A BROAD VIEW

(a) An Iron Mile

The general position can be initially illustrated by a few field notebook entries for the first intensive season's search and excavation at Jaong, which is in aggregate probably the *least* slag-rich of the three main sites. First, an early 1952 trench there:

Jaong Trench C/1 and the Question of Quantity

The first 2" layering of 1952 was based on experience at the Bongkisam (Santubong) end 2 miles away in 1950. As indicated above (p. 38), this trench was initiated on May 25. On TH's return, he found CBK literally loaded down with iron slag, on a scale unprecedented even in the most ferrous sections at the Santubong (Bongkisam) end, which we had thought the centre of the iron working rather than this deserted creek. Once more, the Jaong had surprised us!

As the object of this sample was to obtain one statistical basis for the calculation of quantities involved, the labour of sifting tens of thousands of pieces of metal had necessarily gone on for six days and down to 26". This can be compared with 1950 (Bongkisam) thus:

Depth (inches)	Jaong	Bongkisam
0 - 6"	Iron slag	Dense Iron
6 - 12"	Dense Iron slag	Fair Iron
12 - 18"	Very dense	As above
18 - 24"	Very dense	As above
24 - 30"	Sterile white sand and rock	Sterile.

A noticeable factor at this part of Jaong C/1 was the relatively undisturbed terrain. Apart from upsets of erosion, tree roots and rodents, the topsoil seemed to remain much as deposited. Bongkisam has been so intensively cultivated for a variety of crops (and laterly rubber) that much of the earlier topsoil has disappeared.

(T.H., Workbook II, 10.6.52: 71-72)

Little did one know in those days! That early notebook concept of "stratification" proved in the long run too simple. But the impact remains--after 16 years study, then renewed experience there in 1966.

With assistance from a team of senior trainee teachers of Batu Lintang College, Kuching, correlated with the use of mine detectors (see II.7.a), the slag search was extended for over a mile beyond the main excavation site in Jaong that season. Here is part of a field report written in July 1952 by Mr. Chen Boon Kong, Museum research assistant, who helped extensively in this operation:[1]

> Slag has been found on most of the hillocks from the first one north of Batu Gambar to a Chinese plantation about one mile away. Beyond the latter, to Telok Nipah Bay, nothing so far. Mine detectors have been used here and gave us accurate data. Testing trenches were also dug on two of the hillocks along the Ja'ong-Nipah Bay path and in the Chinese plantation.
>
> These three trenches were the series named for the Batu Lintang Training Centre party who gave voluntary help to the excavation, besides clearing the rocks and paths, etc.
>
> Running north towards Bako Bay, the first trench, BL/1, was on so-called "Mango Hill", 250 yards south from Batu Gambar. Thirty inches square, six-inch layering, 119 lbs. of slag resulted (and 7½ lbs. crucible) down to 24".
>
> The second (BL/2) gave 201 lbs., and down to 26" (101 lbs. at 18-24").
>
> The last, BL/3, was in the Chinese plantation belonging to Mr. Lee Teck Huat, previously a teacher at St. Thomas's School, Kuching. This trench was one thousand yards on from BL/2. Result 3½ lbs. slag only.

The last word in the above report, "only," shows the dazing effect that the persistent presence of slag has on anyone as any archaeological season proceeds in this environment. What is so remarkable here is that in a 30" x 30" trench, BL/3, dug ABSOLUTELY at random by yard rule, on a 3000 ft. mark, *there is in fact 3 lbs. 8 ozs.* of iron slag. Moreover, BL/2, 500 yards back, has 201 lbs. under its 6½ square feet of random selected surface. The BL/2 figure is as high as some down in the *main* Jaong site--as we shall see in what follows.

Thus we have an extension of over half a mile toward Bako Bay, from the creek landing place through Batu Gambar to the old schoolmaster Lee's quiet house among the mangoes and coconuts.

Recapitulating for all this outlying part, another field note of the time puts it reasonably well:

> The Buntal End
>
> The piece of *occupied* land nearest to the Ja'ong site belongs to Mr. Lee Tek Huat. He visited Raso camp on 8.6.52 and informed us that there was a track across to Buntal Bay and that much slag and pottery were to be found over that side.
>
> On 9.6.52 he kindly sent his nephew to conduct us that way, and at the same time we had a better path cut by the Santubong labour. We had always intended to work in that direction on one of the basic assumptions of the excavation: that the Sarawak River once flowed from the present mouth of the Ja'ong right across into Buntal Bay, although now even the Ja'ong creek runs dry before it reaches that far back and a separate smaller creek flows in the other (Buntal) direction.
>
> There is a slope, a continuation of "Middle Ridge" (see Book II) all the way to Mr. Lee's land boundary, which is in Upper Jaong.
>
> Then swampland with small hillocks, as nearer Batu Gambar. On these (e.g. the little one has a house on it) *quantities of slag near surface*.

Occasionally iron slag and baked clay or sand comes in large accretions. At Jaong trench F/3 of July 1952 one chunk weighed nearly 20 lbs., and was associated with a dense lumpy *layer* continuing for 35 ft. into and under the roots of a fully grown, 100 ftt + jungle tree covering the sector when we cleared it. Again in June 1966 at Jaong we found lumps (cakes) of slag up to 6½ lbs. in Y/3, especially at 24"-36". Seldom are these *mainly* solid slag however. They will break up with a hammer into small components of fusion, suggesting a clay wall to some sort of hearth or other residue, rendered almost unrecognizable by activities underground (cf. II.9-10 for discussion).

Such lumps are not the general rule in any case. 99% of the slag comes in separate, hard, unbreakable, fully metallic pieces, directly from heating then cooling into solid form. These are scattered over very many acres.

(b) Sweep of the Slag Through the Delta

The approximate strength and scatter of slag as now known in the delta and immediately adjacent sub-coastal area can be broadly stated:

(i) *Jaong*: from the Raso creek junction at the jetty made from excavated slag (1955-66), nearly through to Bako (Buntal) Bay, 1450 yards x 20-40 yards following the old creek line, plus some offshoots and outlines seldom below 48" depth (for general character of this and the two following sites see I.3.b above).

(ii) *Buah*: concentrated at end of creek from jetty made of excavated slag, widely over flat-land orchard, 100 x 400 yds. to maximum 120" depth (much often 72"); and extending more thinly round foot of Buah hill on inland side for at least 800 yds. along 20-40 yd. strip on flat (and in mud silting).

(iii) *Bongkisam*: concentration near head of creek above Santubong bridge, 200 x 100 yds. to *ca.* 48" depth; then a long, uneven, almost continuous strip parallel to main river through Kampong Ayer (iv below) *ca.* 1,2000 x 30-50 yds.

(iv) *Ayer*: thinner continuation of (iii), petering out along land track which continues to Jaong: 200 x 25-45 yds., and outliers, av. to 36" (for general character of this and following sites see I.3.d above).

(v) *Bukit Maras*: sporadic slag scattered thinly over lower hillside behind Bongkisam for 600 x 100 yds.

(vi) *Muara Tebas*: irregularly around village area, *ca.* 300 x 20-30 yds., shallow.

(vii) *Telok Serabang and Sematan area*: irregular small sites spotted along behind the coastline and up Sematan River tidal reaches; total surveyed approximately 500 x 20 yds.

(viii) *Temakul*: slag mound almost pure (?), unmeasured (cf. I.3.d.vi above and II.8.a below).

(c) <u>The Iceberg's Tip</u>

All this slag is in low land parallel to and usually within 100 ydsa of a surviving creek tracea None of it is close to the open seashore or coastlinea Seldom does it go uphill for more than a few feet, except on Bukit Maras and along the Jaong crest past the Batu Gambar petroglyph--the latter rising from 30 to 50 fta above river level.[2]

Not only is the slag located and diggable on land, it is also to be found in the mud and present creek beds, though here very difficult to follow up. Special attention was paid early on to this aspect in the vicinity of Jaongȧs Batu Gambara Here is another extract from a workbook of that perioda

> Trench M/3 is 134 feet down track from M.1, at tide level M.2/2. Strike water at 6". Even so, there is slag, some ceramicsą and 3 *beads* (1 agate) herea A *cut* stone in situ only just aboveą at edge M.2/1. This M.2/2 is *covered* with salt water at spring tide and very difficult indeed to work now as Nipah growing. Even at low tide wateraonly 6" below surface. (T.H., VIII, 19.7.52: 435-439)

Or again, the day before at trench M/1:

> 84 fta fromacorner E/1 and E/2. A *selected* trench because of a "cut rock" just flush with ground surface, exposed through wear and tear of our path to Raso Camp. Much slag all around as rock is dug out to swamp level.

There is good reason, on these prehistoric indications and the known historical reaord of massive silting and rapid overgrowth, to suppose that much *more* slag is currently undetectable in silted up creek bedsą lost river branches and areas now densely given over to mangrove, *nipah* palm swamp and treesa A large part of the slag is now forever lost to human sight or search in the flux of the delta's own prehistorya We have as it were an iceberg of iron here; only the tip shows above watera

II.7. SLAG MEASUREMENT STANDARDS

As work progressed in the delta, the scale of the slag and other remains became so truly astonishing that it proved difficult to describe the prehistoric scene to other people without seeming to exaggerate. Efforts were therefore made, over the years, to express the situation in objective, and where necessary in numerical terms. This is not easy in this complicated terrain and with such unattractive, dirty, incidental material. But that is what this and the following chapter are about. It is hoped, too, that some of these measurements may be of use to others and eventually lead to comparative studies over a much wider area. In any case, it is very important to be able to recognize and define the scale of the prehistoric Santubong operations, and prove that this is in fact not easily exaggerated.

(a) Mine Detector

Once it was found that iron slag--and to a much smaller extent iron objects--were so frequently, almost invariably, part of the delta's prehistoric message in the ground, the difficulty of surveying the relevant sites, largely then overgrown and inaccessible, was reduced. At this time, in the fifties, T.H. was Commandant of the Sarawak Special Constabulary, and was able to call on help both from outside and from local volunteers, who trained local personnel in the use of Army Mine Detector Type No. 4.A.[1] This effective machine is readily handled and a pack weights only 25 lbs. It will normally detect iron with a distinct *ping*, at 22", but slag proved sluggish at over 12", partly perhaps owing to its lower metal content. The main difficulty in use was clearing paths through the underscrub so that the "search coil" on the machine could be kept close to the generally uneven ground surface. Even then, of course, where no slag was nearer the surface than, say, 24", it would not be detected. Subsequent excavation has shown this situation is rare, and that if slag is present, at least some of it nearly always starts closely sub-surface. Exceptions are as at Jaong trench E/2 x 20 of 1952, for instance:

> Little iron slag in 0 - 12", becoming *very abundant* at 24 - 30". (CBK, 9: 21)[2]

Also, Q/1 x 3 of 1952:

> No slag in top 0 - 6" but occurring in limited quantities in 6 - 18". (CBK, 29: 35).

But such cases are rarea

(b) <u>Excavation: Weights and Depths</u>

Working from the mine detectors, from local information in cultivated areas, and on surveyed cross-sections at measured distances radiating out from man-proved foci, and using methods of systematic layering, hundreds of trenches were dug in delta sites to test for slaga This was then measured by weight in selected sectors, otherwise recorded on simple visual criteria (based on tested weight standards) by the persaon in charge at the sitea

Slag was weighed whenever other work permitted and where the results seemed useful, over the yearsa As such weights are usually high and need not be refined for this sort of material, a simple, hearty, pound and ounce avoirdupois scale was normally employeda Where detail is not required, weights are given hereafter to the nearest pound (lb.).

Normally all weights were taken "dry": that is, after the slag has been exposed to sunlight and open air for some hours (usually 24) after excavation. But this can be a tedious and expensive business, especially if time is limiteda Other workers might prefer to weigh and discard at once after extractiona

Clearly weight on extraction--here termed "damp weight"--can be affected by previous rainfall, ground drainage, surrounding soil character, etca A check on the difference was made on 18a6..66 at Jaong (at trench X/1)a It should be emphasized, however, that whenever "slag" is here taken as a category, there may be accretions of cinder, clay, ash, or earth which cannot be separated in bulk by ordinary fielda methods (cf. IIa9). These may represent as much as a tenth,a especially in the deepest levels subject to pressure, but rarely goes over 5% and at a minimum (e.g., where surface rain-washed) under 1%. There is nothing one can do to meet this factor in everyday Borneo field practicea This gives a loss of between 5% and 9% in main slag-rich sectorsa That margin must be allowed for in any comparisaon of damp and dry resultsa The variations in loss on drying may be due toa minor factors such as the time of day of excavation, sun on the trench face, interval between excavation of damp weight, atmospheric humidity, etca, and need not be regarded as significant for the scale of measurement with which weaare

Jaong: Test of Slag Weights, 1966

	"Damp" Weight		Dry Weight		Loss Difference	
	lb.	oz.	lb.	oz.	lb.	oz.
0 - 6"	23	12	22	7	1	5
6 - 12"	30	6	28	14	1	8
12 - 18"	32	4	29	10	2	10
18 - 24"	42	10	38	6	4	4
24 - 30"	63	0	59	2	3	14
30 - 36"	103	6	96	6	7	0
36 - 42"	41	10	40	4	1	6
42 - 48" (wet base)	1	8	1	0	0	8

presently concerned. But it is important to be clear on this; if other investigators are to compare results elsewhere (as we hope).

So, as a working basis, we can take it that on-the-spot quick weights may run up to 10% more than when fully dry: usually nearer 5%, however.

For broad quantitative delta statements hereafter, dry weights are considered (unless otherwise stated). For easy comparison within the limits of this method, weights per trench or layer were at first calculated and stated as "per 100 per cubic feet" of excavated deposit, which seemed a suitable unit. This proved quite effective within one site with fairly even depth like Jaong. But it produces complications when strictly applied to Buah's very deep slag deposit compared with Jaong or Bongkisam, which are often shallow.

(c) Another Slag Index: Weight per Surface Square Foot

To consider the depth of the deposit is of course highly relevant in any orderly archaeological excavation. But in most delta sites we have found that the stratification is slight, non-existent, or highly complex through disturbance. The sites were mostly occupied or used with intensity over relatively short periods and the human deposit over bedrock or sterile sand (or clay) is usually piled up higgledy piggledy in a rich rush, not through the slow accretion of many centuries, but the intense multiple activities of few.

In the case of slag this effect is multiplied. The slag was not "deposited" piece by piece as the residue of ordinary human life over generations of populationa-as, for instance, is bone and shell in Niah Great Cave. Rather it was accumulated here and there a bit at a time, sometimes a big lot in a very short time--a single dayås smelting could make a glorious mess, especially when repeated again and again over the same spot over several years.

Therefore, while the depth of slag (and crucible if associated) is of importance and can be illuminating, this may be controlled by several vicarious factors varying in depth from point to point without this reflecting a longer or shorter *period* of humanaslag-activity in terms of time. In order, then, to measure more generally in quantitative terms, the *surface* area of the trench was also especially considered. A trench 5 feet broad and wide is 25 square feet. If this trench contained, from surface up to bedrock, 25 lbs. of slag, that would give a factor of *1 lb*. per square foot. If it held 2,500 lbs. of slag--as some trenches would--then a factor of 100 = 100 lbs. per square foot of overlying surface. Or, put another way, *under* 1 square foot at that point lies 100 lbs. of slag. Jaong X/2 of 1966, for instance, 2.5 square feet, gave a figure of 148 lbs. per square foot. The method was found helpful, if somewhat rough. It also worked for other artifacts and could be a handy future yardstock for other excavations.

(d) Counting the Pieces

The counting of slag pieces in the field is often impracticable, very slow, and can be a bit misleading. But the relationship between weight and number cannot be ignored as irrelevant and was the subject of a separate study described at II.8 below (also II.9).

II.8. SOME QUANTITATIVE SLAG RESULTS

The slag, as we have seen, stretches in deposits from small mounds to wide acres, from behind Tanjong Datu at the Kalimantan Sarawak border for many miles across to the far eastern mouth of the great delta system terminating eastward at Muara Tebas. At a series of stations just behind the coastline or within a mile or so up the delta creeks, there are slag deposits at an intensity reaching over 150 lbs. per surface square foot. On a moderate calculation significantly many tons are involved. And this is only:

(i) the slag, the useless residue of iron smelted from ore;

(ii) that proportion of slag that has been discovered on dry land since 1950 and which has been subsequently systematically surveyed;

(iii) thus this is not allowing for

a. undiscovered land sites;
b. all the other slag not *now* on dry land, in swamp, creek and river beds, estuaries (the bottom of the iceberg).

Consistent with the nature and complexity of the raw material, all this is now presented as objectively and briefly as possible.

(a) Heaps and Scatters

In other parts of the world prehistoric iron industries have often been identified from the impressive heaps, sometimes minor mountains, of slag left to mark the spot.[1] It is negatively conspicuous that there is no such landmark in our delta sites. On the contrary, the diffusion and lateral spread of the slag deposit is one of its diagnostic characteristics--even to the point of scraps of slag in places where it could not have been actually produced right there (cf. II.11-12).

The single exception to this "rule" has not been proved as contemporary with the main delta sites, but is very unlikely to be otherwise. It therefore merits special notice. This one known slag "heap" for Sarawak is in mangrove swamp on the little Temakul creek which runs west from thetmost westerly large exit of the Sarawak River, at Sibu Laut, 3 miles west of Santubong, about 400 yards behind the long, straight coast beach there. It is a real solid slaggery seemingly *without* related ceramics, so far as is known. This covers at least 120 x 30-40 feet. It has acquired a special prestige and became part of the local graveyard when Sibu Laut was settled by Malays after 1850 A.D. It is not therefore practicable to excavate the place, without causing distress.

Without excavation, a rough estimate here gives perhaps 100,000 lbs. of slag gross weight. A sample of Temakul slag shows no apparent significant variation in size, shape, texture, etc., when compared with a basic type series.

(b) Initial Visual Classification

The first big delta dig, 1952's excavation at Jaong, was principally concerned with ceramics, and the main work was done in parts rich in stoneware and earthenware, not soaked in slag. The main sector excavated was series E/F, covering 950 square feet selected primarily for its "trade goods," if anything to avoid slag richness. The broad average pattern of slag was expressed by visual assessment only at first:

Jaong, 1952: Slag Visual Frequency Check

Depth (inches)	Trench Size (feet)						
	E.1 5x40	E.2 5x40	E.3 5x40	F.1 5x20	F.4 5x10	F.6 5x20	F.7 5x20
0 - 6	✓	X	✓	✓	X	XX	XX
6 - 12	✓	XX	X	X	✓	XX	XXX
12 - 18	✓	XX	XX	✓	0	XX	X
18 - 24	0	XXX	XXX	0	0	✓	0
24 - 30	0	XXX	X	0	0	0	0
30 - 36	0	X	✓	0	0	0	0
36 - 40	0	0	0	0	0	0	0
40 - 48	0	0	0	0	0	0	0

Slag frequency code in above table:

0 = absent
✓ = present (a little)
X = moderate
XX = considerable
XXX = much

S/1-22 was a set of twenty-two trenches in sequence continued on from the main 1952 Jaong site, grouping these in adjacent threes:

Jaong, S/Series: Slag Visual Frequency Check

Depth (inches)	S/number						
	S/1-3	S/4-6	S/7-9	S/10-12	S/13-15	S/16-18	S/19-22
0 - 6	XX	XX	XX	XX	X	✓	X
6 - 12	XXX	XXX	XX	X	✓	✓	X
12 - 18	XX	X	0	✓	0	0	✓
18 - 24	✓	X	0	0	0	0	0
24 - 30	0	0	0	0	0	0	0

(For key see foot of previous table.)

In the S/series the slag was more shallow, corresponding with an underlying bed rock around 30", compared with 48" at E.

These two cross-sections are indicative of a recurring style in slag deposition, even away from main concentrations of working in "obvious" places, such as a creek junction with level ground. They indicate also the variation from trench to trench--which could be consistent, of course, with an irregularly spaced distribution of "furnaces" or other working points. Finally, they share the tendency for slag to be most abundant below the top soil 6", and above the bottom 6", though here other complications come in, to be examined below.

(c) Some Measurements by Weight at Jaong, 1952

C/1, 5' x 5' square at Jaong was the first of a long slag-study sequence on a quantitative basis. Excavated in 2" layers, the slag was dry weighed and subsequently recalculated in terms of lbs. per 100 cubic feet on the basis of each three sucessive 2" layers grouped (= 0-6", etc.):

Jaong C/1 Slag Weight

Layer (inches)	Lbs. per 100 cubic feet
0 - 6	1,104
6 - 12	1,104
12 - 18	2,296
18 - 24	1,712
24 - 30	0,036

Here we get a more precise expression of the visual classifications previously tabulated. At this stage, one also comes up against the problem of crude weight as meaningful in terms of the actual slag-producing operation. The visual method has the advantage of giving an impression of the slag "as a whole." More impersonal and "scientific" weights can slightly obscure the issue (if, for instance, in one case a few very heavy pieces and in another a great many tiny ones turn the scale). Here, for once, the delta sites gave a little methodological help. For analysis shows that though there are some very big (especially at Bongkisam) and some very small slags, on the whole they come in smallish pieces, running several to the ounce at all sites and levels. The way this works out and what it may mean in detail are critically examined in the following chapters, but need not detain us at this stage in the total evaluation of the deposits.

For comparison with the C/1 results just given, a further series of nine trenches, each 30" x 30" square (quarter the size of C/1), in a direct line upstream at right angles to C/1 at 50 ft. intervals, along the creekside slope of Batu Gambar hill, towards the Santubong River. These therefore cover a line of 150 yards, at regular intervals, *outside* the main area for stonewares, earthenwares, and other non-metal remains; and also outside the main slag sectors, in a visually unimposing part of the site:

Jaong, D/Series: Slag, in Weight per Layer: Dry Total
(to nearest lb.)

Depth (inches)	1 - 3	4 - 6	7 - 9	Total	Total as Percentage
0 - 6	31	179	133	343	24
6 - 12	12	281	363	656	47
12 - 18	1	180	154	335	24
18 - 24	0	9	39	48	3
24 - 36	0	0	26	26	2
36 - 42	0	0	1	1	-
42 - 48	0	0	1	1	-
Total	44	649	717	1,410	100

In this D sector, the slag is markedly high in the deposit; indeed nearly 95% is in the top 18", and approaching a third in the top 12", or, if calculated as previously for C, just under *5,000 lbs. per 100 cubic feet*. But here, as elsewhere, it is essential to recognize that such apparent stratification is heavily influenced by the previously mentioned disturbance factors, as well as by weathering and loss of topsoil from above or the intrusion of boulders and the geological influences, establishing a very highly uneven sterile bottom level below. These and the following figures must therefore be treated with usual delta caution as regards any *fine* gradations of vertical distribution, while retaining a general validity, and reporting accurately on the gross position in every part of the sites. With this qualification clearly in mind, we may take two more Jaong examples from the many available for comparison. G/1-3, all 30" x 30", ran again at 50 ft. intervals, at *right angles* to C across the crest of the Batu Gambar hill; H/1 is a larger trench, 5' x 5' in a relatively clear place of arid sandy soil with *very* low human fragmentation, on the Santubong side of the Gambar ridge--*all* artifacts were also at a minimum here, we are moving too far back from the Jaong creek into archaeologically sterile terrain; H/1 itself expired downward at only 12".

Jaong G/1-3 and H/1: Slag Weights

Depth (inches)	G/1-3	H/1
0 - 6	14 lbs.	0 lb. 2 oz.
6 - 12	102	1 lb. 7 oz.
12 - 18	140	0
18 - 24	172	0
24 - 30	185	0
30 - 36	31	0
Total	644 lbs.	1 lb. 9 oz.

As usual, the slag is concentrated *below* 6", even in the thinnest slag positive deposit as at H/1. Incidentally,t *nowhere* in the Jaong site was slag showing on the surface when this work began, and the same applies to Buah--it was superficially exposed only at small parts of Bongkisam, especially around the outskirts of the bridge. In case it requires any confirmation, this underlines that there was *no* slag-producing activity in the delta sites postdating the processes which are dateable before 1400 A.D. through the other artifacts. The whole place went "dead"--for at least three centuries.

(d) Inch by Inch

It seemed useful to take trouble and calculate this stratification even more precisely for the record, even if only to illusatrate the degree of any iron variation and "inconsistency" within the broad framework of slag all the way from sub-surface to bedrock, but tending (only tending) to concentrate somewhere around the middle level, above or below. For this purpose, two already exposed deposit faces were selected at random in a relatively slag-rich part of Jaong in 1966, for excavation 6" back along a 5' face (that is, 2½ square feet). Every object was taken out and analyzed in detail for precisely measured layers of 1" from surface to the sterile base, which proved to be 48" in each case. These two not-to-be-forgotten varieties of slag-picking concerned trenches X/3 and M/2, as detailed below:

Jaong, 1966, X/3 and M/2: One Inch Slag Layering Study

Depth (inches)	X/3 Iron lb.	X/3 Slag oz.	M/2 Iron lb.	M/2 Slag oz.	Depth (inches)	X/3 Iron lb.	X/3 Slag oz.	M/2 Iron lb.	M/2 Slag oz.
0 - 1	1	14	0	8	24 - 25	9	0	0	8
1 - 2	2	0	0	4	25 - 26	12	4	1	0
2 - 3	6	0	1	0	26 - 27	10	8	0	14
3 - 4	6	10	2	0	27 - 28	8	4	1	0
4 - 5	6	0	3	12	28 - 29	7	12	1	0
5 - 6	6	0	3	8	29 - 30	14	2	0	8
6 - 7	7	14	2	4	30 - 31	11	3	0	6
7 - 8	7	4	3	12	31 - 32	9	7	3	2
8 - 9	4	4	2	8	32 - 33	14	4	4	9
9 - 10	3	4	2	8	33 - 34	19	0	5	2
10 - 11	3	10	0	14	34 - 35	12	7	2	12
11 - 12	6	0	1	12	35 - 36	17	8	3	9
12 - 13	7	8	0	14	36 - 37	11	6	1	9
13 - 14	6	4	0	4	37 - 38	6	11	2	4
14 - 15	7	4	0	12	38 - 39	6	14	3	1
15 - 16	4	4	1	0	39 - 40	4	12	6	14
16 - 17	5	12	0	14	40 - 41	1	7	3	14
17 - 18	10	4	1	7	41 - 42	0	15	3	12
18 - 19	8	0	1	10	42 - 43	0	12	4	2
19 - 20	7	7	1	8	43 - 44	0	13	6	0
20 - 21	22	10	1	0	44 - 45	0	8	12	4
21 - 22	9	0	1	0	45 - 46	0	14	7	0
22 - 23	6	8	0	10	46 - 47	0	2	2	10
23 - 24	7	8	0	12	47 - 48	0	2	0	4
					Total	349 lbs.		113 lbs.	

There is three times as much slag in X/3 as in M/2 (349 to 113 lbs.), largely because of the fairly distinct concentrations in various inch layers between 20-21" (the highest) down to 36-37". Eleven X/3 inches held over 10 lbs. of slag --nearly all of it in small pieces, and this effect certainly not produced by large single lumps in either of the trenches. There are 84 lbs. of slag in the six inch layers from 31" to 37", which is equivalent to over 2,500 lbs. per 100 cubic feet on the basis of the ore rich Jaong C/1 calculation previously citedt that is, very high. Such vertical concentrations, both because of and despite their irregularity, are possible indicators of the run-off of slag in series of episodes buried by further series--and suggestive of a method to be considered subsequently (cf. II.10.d). Pointing the same direction also is the big concentration deep in M/2, with 25 lbs. in three inches at 43-46"--compared with 2 lbs. for the corresponding levels of X/3.

It should here be emphasized that X/3 and M/2 do not represent the maximum slag concentration at Jaong. It will put the finer layering of those two samples in better perspective if they are tabulated side by side with other Jaong trenches for which slag was measured on a less elaborate scale during this 1966 season. X/1 and X/2 are part of one sector with X/3, likewise M/1 with M/2, all five trenches of the same size (5' x 6" each), whereas Y/2 in another sector is larger (at 5' x 6')--a point to be borne in mind in considering the following table, in which the figures for the two largest trenches are italicized:

Jaong Slagt Weights to Nearest Pound

Depth (inches)	X/1	X/2	X/3	M/1	M/2	Y/1
0 - 6	24	20	*28*	10	*11*	
6 - 12	39	39	*35*	12	*14*	554
12 - 18	36	50	*41*	6	*6*	
18 - 24	46	86	*62*	6	*6*	960
24 - 30	64	141	*62*	3	*4*	
30 - 36	100	85	*84*	13	*19*	155
36 - 42	43	40	*32*	20	*21*	
42 - 48	2	(-1)	*5*	38	*32*	0
Total	355	460	*349*	108	*113*	1,669

It will be seen that the vertical slag features in X/3 are closely paralleled in its two collaterals; much over half of the slag in each case is between 18" and 36". In the same way, M/2 is consistent with M/1, both representing a phase-out to slag-poor; in these two trenches, though, only about a quarter falls between 18" and 36"--and over half down at the bottom 12", an unusual but by no means unique feature.

To finalize this comparison, in the broadest terms, the next table reduces Y/1 to the same size-scale as the other trenches cited above and cites all as percentages also:

Jaong Slag: Weight to Nearest Pound,
All Corrected to Scale of X/1

Depth (inches)	X/1 and X/2 (Average)		X/3		M/1 and M/2 (Average)		Y/1	
	lb.	%	lb.	%	lb.	%	lb.	%
0 - 12	61	15	64	18	23	21	55	33
12 - 24	110	27	103	29	11	10	96	58
24 - 36	195	48	146	42	20	18	15	9
36 - 48	42	10	37	11	56	51	0	0
Total	408	100	350	100	110	100	166	100

(e) Comparison with Buah

Moving from Jaong over to Buah, similar measurements were taken there later in June and into July 1966. Here the slag is much more concentrated than at Jaong, or at least a lot more of it is piled up deeper in one smallish sector near the creek. In previous years, Sarawak Museum teams had excavated out most of this, so that for fresh test trenches it was necessary to work slightly off center, on the inland (hill) side of the original slag-knoll.

A cement marker put down for the inner limit of *major* concentration as assessed in 1955 (at D/1 - D/4) was taken as start line for a new trench series, W, here. As in the Jaong study, a first trench was made (in 6" layers) to clear the old exposed face, (W/1); then a further trench on the face freshly revealed, at 1" layers (W/2). Buah W/1 should thus be broadly comparable to Jaong's X/1 and X/2 done in the same way; Buah W/2 should be closely comparable, in this respect, to Jaong's X/3. The Buah deposit, is, of course, much deeper at this point, as the following table shows:

Buah: W/2 Slag in 1" Layers

Depth (inches	Iron Slag lb.	oza	Depth (inches)	Iron Slag lba	oz.
0 - 1	1	0	42 - 43	4	8
1 - 2	0	6	43 - 44	3	4
2 - 3	0	5	44 - 45	5	1
3 - 4	0	5	45 - 46	6	7
4 - 5	0	2	46 - 47	4	4
5 - 6	0	1	47 - 48	3	9
6 - 7	1	0	48 - 49	3	12
7 - 8	0	4	49 - 50	7	8
8 - 9	0	7	50 - 51	2	15
9 - 10	0	9	51 - 52	2	2
10 - 11	1	3	52 - 53	2	3
11 - 12	1	1	53 - 54	3	4
12 - 13	1	6	54 - 55	1	15
13 - 14	1	11	55 - 56	5	13
14 - 15	4	5	56 - 57	3	5
15 - 16	3	11	57 - 58	2	2
16 - 17	2	11	58 - 59	4	8
17 - 18	2	5	59 - 60	6	1
18 - 19	1	13	60 - 61	10	9
19 - 20	4	1	61 - 62	0	13
20 - 21	4	15	62 - 63	2	7
21 - 22	5	14	63 - 64	1	8
22 - 23	6	6	64 - 65	1	8
23 - 24	3	0	65 - 66	2	8
24 - 25	2	10	66 - 67	2	9
25 - 26	0	12	67 - 68	2	7
26 - 27	0	10	68 - 69	2	10
27 - 28	0	14	69 - 70	4	2
28 - 29	0	12	70 - 71	3	3
29 - 30	1	9	71 - 72	3	4
30 - 31	2	4	72 - 73	3	10
31 - 32	2	12	73 - 74	4	0
32 - 33	3	4	74 - 75	1	3
33 - 34	4	4	75 - 76	1	0
34 - 35	4	2	76 - 77	1	0
35 - 36	3	14	77 - 78	1	0
36 - 37	6	4	78 - 79	2	0
37 - 38	5	15	79 - 80	-	-
38 - 39	4	9	80 - 81	1	4
39 - 40	4	8	81 - 82	0	2
40 - 41	3	11	82 - 83	0	8
41 - 42	4	0	83 - 84	0	7
			Total	231	11

The situation parallels that already shown for Jaong, with sometimes erratic bands of more or less metal. Again, there is a tendency to concentration around a median level, although this is necessarily deeper at Buah. Considering the layers for W/2 and comparing with adjacent W/1 at Buah we have:

Buah W/1-2: Weight to Nearest Pound

Depth (inches)	W/1		W/2	
	Lb.	Percentage	Lb.	Percentage
0 - 12	3	2	7	3
12 - 24	15	8	42	18
24 - 36	21	11	28	12
36 - 48	48	25	56	24
48 - 60	53	27	46	20
60 - 72	34	17	37	16
72 - 84	19	10	16	7
Total	193	100	232	100

About one-half of all the slag in these trenches is in the lower 3 ft. (48" - 84") and only a third in the top 2 ft. Or, put another way, 48% of this Buah slag is at depths which would be sterile sand or bedrock at Jaong (and likewise Bongkisam). Crude comparisons can be misleading, but a more judicious examination will be helpful.

(f) Main Depth Comparisons: Jaong, Buah, and Bongkisam

The Buah deposit at its main slag focus is about twice as thick as any other in the delta, and sometimes more. Yet in general vertical characteristics it broadly conforms to the Jaong (and Bongkisam) distributions, both as regards overall tendencies and intricate variations. At this point in Buah repetitive slagging went on either longer or more extensively than elsewhere--there is nothing in the site itself to suggest any particular "reason" for this, except possibly the excellent supply of fresh water off Buah hill flowing towards a creek junction and nice flatland at this point (but this may very well *not* have been the same flow and terrain 600 or so years ago). Putting the main relevant figures for both sites into percentages for easier comparison, we can see the picture perhaps as well as it can ever be seen. A sample figure for Bongkisam is included also; see particulars in section (g) following:

Bongkisam, Buah, and Jaong Compared: Slag Weights
As Percentages of All Slag per Trench Unit

Depth (inches)	Buah	Jaong		Bongkisam
	W/1-2 (Average)	X/1-3 (Average)	M/1-2 (Average)	Z/1-6 (Average)
0 - 12	2	16	21	29
12 - 24	14	28	10	61
24 - 36	12	46	18	10
36 - 48	24	10	51	--
48 - 60	23	--	--	--
60 - 72	17 } 48	--	--	--
72 - 84	8	--	--	--
Total	100	100	100	100

In all these examples--and many others not here included as repetitive--there is thus a marked concentration of slag in the median to lower levels, despite all local variantsa Too many possible factors, natural and man-made, prehistoric and protohistorica have operated to make point to point explanations of the variations as implausible as they would in any case be uninteresting. But it is also manifest that the slag is nowhere anything like the whole deposit--as we shall handsomely see when we come to other associated artifactsa Equally, even where it is strongly concentrated within any one vertical stretch, there is always *some* slag in the non-concentration level alsoa

It really is rather astonishing that *in every single one of the 48 x 1" layers at both Jaong X/3 and M/2, there is slag presence from bottom to top*; in only two 1" layers were there less than 3 oza; and that means, in this case, less than 100 slag *pieces*. In all the 84 x 1" Buah W/2 layers, four have under 3 oz.; and *only one has the unique position of being "slagless"* (i.e., not enough to make 1 oz.): 79-80", almost the bottoma

(g) Bongkisam Tends Shallower Again

Over 50,000 lbs. of slag were taken out of Bongkisam trenches in the 1955 season there alone. The subsurface distribution pattern followed very much the same lines as Jaong, and nowhere reached Buah-type depths. For the most part, the Bongkisam deposit is more shallowly deposited than Jaong's, as illustrated in the preceding table, which takes six Z/series trenches, involving 380 lbs. of slag carefully check-excavated in the vicinity of the shrine there, where--as widely in this site--the deposit reaches sterile white sand and small sandstone rocks about 36" or earlier.

The median line concentration therefore goes up relatively at Bongkisam--and in the Z/series, for example 38% out of the 61% slag in the middle layer of 12-24" was in the lower part thereof, at 12-18". The figures by 6" layers weret

Bongkisam: Z/1-6, Slag Layer Percentages

Depth (inches)	Percentage of total slag by weight
0 - 6	8
6 - 12	21
12 - 18	38
18 - 24	23
24 - 30	8
30 - 36	2
Total	100

(h) Kampong Ayert Between Jaong and Bongkisam

Ayer has earlier been indicated as the end run-out of the Bongkisam slag field going upriver towards Jaong (II.6.b.iv). The slag stops for over half a mile and does not resume until the Raso brook is crossed close to the Jaong creek.

Ayer had not been investigated since 1952. As there was a little time and energy left over at the end of the 1966 season, T.H. did four layer trial trenches there after S.O'C. had to return to Cornell, mainly testing the slag at that outer limit. This deposit showed even shallower than Bongkisam:

Ayer: Slag Weights to Nearest Pound

Depth (inches)	W/A 10' x 5'	W/B 5' x 5'	W/C 5' x 5'	W/D 5' x 5'	Total lb.	Total %
0 - 6	176	85	48	18	320	64
6 - 12	90	10	18	26	144	29
12 - 18	9	1	1	22	33	7
Total	275	96	67	66	497	100

The outstanding feature here is the high proportion in the top 6". This may be due to extensive human movement in Everett's time all over the area excavated, reducing as well as compressing the top soil to a greater content than on any of the main sites. There is no question that this slag is of the Bongkisam period; and as at Bongkisam there are more large slag chunks than elsewhere (on this see II.9.e), associated as usual with Sung stonewares and early glass.

(i) Surface Square Feet (cf. II.7.c)

The statistical data used in this Data Paper are not intended to do any more than express in recognizable international numbers the facts of what has been excavated. At no point are they supposed to deserve any great emphasis or have any special merit, except in support of the ideas upon which the whole treatment of this material is based. For this reason, elaborate numerical techniques have been avoided, the whole kept as simple as possible. In concluding this discussion of slag quantities we may therefore be allowed a little license to indulge in a minor exercise of mildly questionable validity to attempt some answer for the obvious overlying question: *how much slag is covered by that term, "delta sites"?* An answer, however incomplete, will assist in understanding the whole texture of what we are examining, in iron and other terms too.

In earlier sections of this chapter we have used figure forms including "lbs. per 100 cubic feet." These give likeable results like 1,104 lbs. and 2,296 lbs. in layers of Jaong C/1. If we took the Jaong X/1 slag, for example, and recalculated it by 12" layers this way we would get:

0 - 12"	2,745 lbs. per 100 cu. ft.
12 - 24"	3,288 lbs. per 100 cu. ft.
24 - 36"	6,560 lbs. per 100 cu. ft.
36 - 48"	1,785 lbs. per 100 cu. ft.

A remote little trench of the BL/series beyond Jaong towards Bako Bay would give 1,328 lbs. in the same terms. The same trench, BL/2, expressed in the alternative formula of "*per surface square foot*," would be 32. This, for reasons already indicated (II.7.c, *et seq.*), seems to be a simpler and more descriptive way of saying what slag there is at any particular place: that is, how many pounds of slag there are *under* one square foot of ground at that place.

Adopting this surface square foot measure, the whole of the properly explored delta deposits might be classified into four main categories:

(i) Over 50 lbs. per s.s.ft. = *concentrations* (parts of Bongkisam II, JJ, Buah at the creek-head excavated in 1955, and Jaong in the rock-carving area of 1952 ran over *500 lbs. per s.s.ft.*).

(ii) 25 - 50 lbs. per s.s.ft. = *slag strong*, definite major prehistoric iron activity.

(iii) 5 - 25 lbs. per s.s.ft. = *slag moderate*, definite but not necessarily major and certainly not prolonged activity, mostly outlying or peripheral sectors.

(iv) Under 5 lbs. per s.s.ft. = more "*casual*" secondary residual or "ritual" slag. (See II.11 on scatter at page 75; also II.12.)

Turning back to some of the trenches discussed earlier in this chapter, they can be arranged in a sequential framework:

(i) Over 50 lbs. per s.s.ft.

Jaong	X/2	184.0
Jaong	X/1	142.0
Jaong	X/3	139.6
Buah	W/2	92.8
Buah	W/1	77.2
Jaong	Y/1	66.8

(ii) 25 - 50 lbs. per s.s.ft.

Buah	W/3	46.1
Jaong	M/2	45.2
Jaong	M/1	42.8
Jaong	BL/2	32.0
Jaong	D/1-9	25.0

(iii) 5-25 lbs. per s.s.ft.

Jaong	G/1-3	19.0
Jaong	BL/1	18.0
Bongkisam	Z/5	17.8
Buah	66/E	14.1
Buah	DA/17	13.8
Bongkisam	Z/4	9.9
Bongkisam	Z/6	7.0
Jaong	A/3	7.0
Jaong	A/4	6.3
Bongkisam	Z/3	5.8
Ayer	W/A	5.5

(iv) Under 5 lbs. per s.s.ft.

Ayer	W/B	3.8
Jaong	A.2	2.9
Ayer	W/D	2.6
Ayer	W/C	2.4
Bongkisam	Z/1	2.0
Bongkisam	Z/2	1.8
Jaong	BL/3	0.9
Jaong	H/1	0.8

Even 0.8 lb. is enough weight to show as between 25 and 80 *pieces* of slag. Very rarely are these small outlier weights derived from other than small--often particularly small--slag fragments (cf. II.9 for piece:weight ratios).

It will be understood that this very rough assortment of sample surface square foot figures is *not* a statistically random cross-section of the whole. It covers a wide range of frequencies, putting emphasis at the lower end of the scale because much effort and careful search has gone into surveying and measuring away from the known, obvious, often wholly excavated site centers in order to ascertain and evaluate the perimeters.

(j) An Estimated Slag Deposit Total

The surface square foot formula can be applied rather easily, if superficially, to the known topography of the delta terrain, slag-wise. This has already been described in II.6.b. Taking the figures given there, the surface square feet proved as slag *positive*--that is, having at least some slag under that surface--can be summarized:

Calculation of Slag Areas Located, 1947-66

Site	(i) Main Slag Area Length x widtht= square yards	(ii) Lesser Slag Areas Length x widtht= square yards	Total Square Yards
(a) Main			
Jaong	1,450 x 30 = 43,500	included in (i)	43,500
Buah	400 x 100 = 40,000	800 x 30 = 24,000	64,000
Bongkisam	200 x 100 = 20,000	1,200 x 40 = 48,000	68,000
Total (a)	103,500	72,000	175,500
(b) Lesser			
Ayer	none	200 x 35 = 7,000	7,000
Maras	none	600 x 100 = 60,000	60,000
Muara Tebas	300 x 25 = 7,500	---	7,500
Sematan	500 x 20 = 10,000	uncertain?	10,000
Total (b)	17,500	67,000	84,500
TOTAL (at+ b)	121,000 sq. yds.	139,000 sq. yds.	260,000 sq. yds.
	= 25 acres	= 26.65 acres	= 53.72 acres

These figures are of course only approximate. Taking a quarter of a million square yards as moderate, this gives 2,250,000 (two and a quarter million) square feet. To be moderate again, say 2,000,000 square feet. *Every foot of this* has slag.

Take theta/i figure above for the three main sites at a found 100,000 (= 103,500) square yardst= 900,000 square feet, of this it is absolutely minimal on the excavation record to estimate:

-- ½ = 450,000 sq. ft. at 100 lbs. per s.s.ft.
= *45,000,000 lbs. slag*

-- other ½ = 450,000 sq. ft. at 50 lbs. per s.s.ft.
= *22,500,000 lbs. slag*

Thus, total for (i) three main slag areast= 900,000 square feett= *67,500,000 lbs. slag.*

Extending this treatment to the category (i) sectors of the lesser (iron-wise) sites:

-- 1/1 = all 17,500 sq. ydst
= 157,500 sq. ft. at 50 lbs. per s.s.ft.
= *7,875,000 lbs. slag*

So, total for all main sectors at *all* sites

= *75,375,000 (say 75,000,000) lbs. slag*

The rest of the slag positive deposit, 139,000 square yards, say 130,000 square yardst= 1,170,000 square feet.

-- ½ = 585,000 sq. ft. at a minimal 10 lbs.
= *5,850,000 lbs. slag*

-- ½ = 585,000 sq. ft. at 1 lbs.
= *585,000 lbs. slag*

Thus, total for all lesser sectors at all sites

= *6,435,000 lbs. slag.*

The result is:

ALL SITES: Estimated slag in gross totals (as calculated above)

	45,000,000	
	22,500,000	
Main slag in main sites		*67,500,000 lbs.*
	7,875,000	
Main slag, all sites		*75,350,000 lbs.*
	5,850,000	
	585,000	
Lesser slag, all sites		*6,435,000 lbs.*
OVERALL TOTAL		*81,785,000 lbs.*

Reducing this 81,785,000 lbs. to short tonst= *40,892* tons. Taking this is round figures, we have 40,000 tons of detected slag residue from the known delta iron industry. It must be emphasized that:

--this is a very conservative estimate (it would be easy to X5 on this, both areas and weight);

--it refers only to discovered slag, on dry land;

--it cannot report the very large amounts of slag believed to be lost in water and mud ("the base of the iceberg"); it would be easy to X5 on this too.

The real slag aggregate of the delta area *could* be imaginatively estimated at half a million tons. But perhaps the point has been made; this slag on any count represents a very considerable, prehistoric activity indeed--especially for those who care to think of Borneo's as a "primitive" economy. And nothing even approaching this scale has been repeated (or suspected) anywhere else in the islands or on mainland Southeast Asia, so far.

II.9. A MORPHOLOGICAL ANALYSIS OF SLAG

(a) The Purposes of This Exercise

This study represents, among other things, a modest initial attack on a reject material which by its very nature lies beyond the threshold of normal, healthy scholarly attention. At least there is no record that iron slag has previously been the subject of this sort of archaeological investigation. In this character anomalous, it has either been ignored or examined on a highly selective basis and by laboratory techniques only. It was thus felt that the attention here directed to this difficult and unglamorous substance in the raw, was justified as experimental search and testing of a suitable field-work methodology for a problem that is a feature of the delta and of many other ancient trading stations, once strung out along the shores of the South China Sea--as well as around the Indian and West Pacific oceans.

These words are therefore offered, with diffidence, to introduce an exercise that to some eyes may seem extraordinary, if not actually absurd? With a minimum of technological background, we have hand-sorted a great mass of slag as if its shape and size had intrinsic importance; and thus became involved in days of painstakingly dull, dirty, doubtfully productive work. This has been done with four hopes in mindt (1) that by setting up at least a preliminary set of criteria for describing slag visually in a simple way, other workers may be encouraged to look at the stuff more kindly; (ii) that similar (or better devised) methods of describing the slag on the spot may enable direct comparisons elsewhere, statistical or otherwise, between the slag products at sites for the Iron Age, different both in place and time; (iii) that the slag shapes described might help interpretation of the now unrecoverable techniques which produced them; and in addition, (iv) that we might clarify our own ideas by handling the muck in this way.

Of these four hopes, the last two have already to some extent been realized. We have learned, for instance, to separate true slag from cinder and other debris, and from metallic iron in other formst this will help in searching for other related sites further afield. We have also realized that the form of slag fossilizes its hot flow, as it came out of the oven, kiln, furnace, crucible or other heat source. In the long run this should help interpret as at (iii). And here some encouragement is received from study of the European literature. For instance, R. F. Tylecote's description (193) of "tap slag" (i.e., slag that has leaked or been allowed to run from a furnace in a semi-liquid state) in an English site (*ca.* 300 B.C.) suggests that "the process must have been carried out at a fairly advanced level." He distinguishes this from, for instance, an Early Iron Age site in Wales with:

> --"a mound containing iron slag of the *primitive* type which had not been tapped."

While the presence of much slag in itself strongly implies smelting of iron ores, nevertheless a vast blacksmith activity--forging wrought iron or making tools--could give something of the same effect, although the smithy process does not produce much slag--virtually none in some existing Borneo methods (VI.36). In the delta case, the slag scale is so great as to make any smithing (only) interpretation truly ludicrous. But the occurrence of tap slag as a consistent, visually discernible type, emphatically proves the use of some sort of furnace (or equivalent) in true smelting. A large part of this delta debris is without doubt "tap slag." Tylecote's Plate XVIII shows "Plan and section of piece of tap-slag from High Bishopley, Co. Durham." It is visually the same as the second commonest of the Sarawak River categories, our (d) "Multifingers" (see below).

(b) Premise and Categories

As a methodological experiment, *categories of shape relationship* were devised. From the apparent chaos of slag fragments seven volumetric shapes were identified as reasonably "typical" on the basis of repeated occurrence. It will be recognized that these are not shapes of crisply ordered geometry, but rather the blurred, rough, residual products of industrial process seen a thousand or so years later by other eyes. Nevertheless, these prehistoric processes were repeated with great frequency, with predictable, patterned gestures and time spans, plus a consistency of measure, temperature and equipment undertaken by a regular continuity of craftsmen with traditional, common skills. Certain regularities in shape should be discernible in the discarded concentrated slag, therefore. For this reject material was not the accidental random product of some wild machine but one end process of deliberate and highly organized human intent. Different men using different methods would produce measurably different forms of fossilized waste. In some cases this could be the *only* way of measuring such differences.

On the basis of sorting several tons of slag at Santubong field headquarters[1] the following categories were established for study (compare Plates 3 to 6 also):

a. *"Tulang Mawas"* ("Ape Bone", P. 3): Slag pieces with two major axes opposed at near right angles, often resembling superficially miniature tools of the early metal age known by this name in West Malaysia (see Linehand, 1951: 12; Tweedie, 1955).[2] The most distinctive of the types (suggesting a *bend* or block in the slag flow?).

b. *Fingers* (Pl. 3): Roughly cylindrical in shape with the long axis at least three times greater than the shorter axis.

c. *Droplets* (Pl. 3): Small pieces with one rounded or hemispheric end, the other being a truncated cylinder: this form could perhaps imply a "drip" or fall vertically and slowly in slag release but see further in Schwaner's ethnographic account (in Appendix B).

d. *Multifingers* (Pl. 3): Slag pieces that appear to be one or more fingers fused together (cf. especially Tylecote, Plate XVIII as indicated above).

e. *Flat-face* (Pl. 4): One face (rarely two) definitely flattened and smoothed, the other side always roughened. These pieces occur in rectangular, roundish and random shapes (see discussion at III.10).

f. *Irregular* (Pl. 4): Not classifiable in a - f; usually non-geometric shaped pieces in which the surfaces show no regularity of plane and in which it is impossible to isolate major and minor axes around which the volume is shaped (N.B. No unbroken slag pieces are naturally quadrangular or *completely* globular).

g. *Cakes* (Pl. 4): Accretions of slag and other materials, often sand, which occur in large and flattish cakes; in these slag cannot be fully separated.

It is recognized that the seven categories could be reworked into a more elaborate system. But smaller units of study would only obscure the rather simple questions one can ask from this sort of material at this stage. Complexity would also create practical problems of recognition and tabulation for an extensive body of evidence. Indeed, on the relatively simple criteria here adopted, the analysis of even a simple, small, specialized trench, X/1 at Jaong (a mere 2½ square feet) proved quite a job. It took 14 man-days for three very skilled men, under supervision, to sort, check, calculate, and weight the slag covered in the table on page --and the resulting layout covered most of the sweeping verandahs at the Government Rest House, Santubong, our 1966 base.

(c) Some Numerical Comparisons (Jaong)

First, the small X/1 trench at Jaong was taken as a base-line for this particular study (see the table on page 58).

"Irregular" is already seen as a large, loose category and could not be reduced except at the cost of starting up a whole series of sub-categories, which appeared too unrealistic until we know much more. That under half are so classified means, in effect, that the remaining 58% of pieces (and 69% by *weight*, see below) conform to the fiarly clear-cut criteria of the other six categories.

Next to examine this by sizet= weight. Where a weight is over 8 ounces, it is classed as 1 pound in the table on page 59; under 1 poundt= X.

The following points are worth notice in regard to depth changes by categoryt

(a) "Tulang Mawas" tend to be more numerous near the surface

(d) Multifingers tend to be relatively more numerous lower down.

(g) Cakes concentrated in 30-36" (cf. 11.10) and generally tend deep.

On the whole, the types do not vary *much* numerically by depth as proportions of the whole.

Jaong X/1: Relationship Between Slag Types and Stratigraphy
(Numbers of pieces of each type)

Depth (inches)	Type (a) "Tulang Mawas"	(b) Fingers	(c) Droplets	(d) Multifingers	(e) Flat-Faced	(f) Irregular	(g) Cakes	Total
0 - 6	164	282	151	197	274	153	193	1,414
6 - 12	78	426	79	215	382	338	164	1,682
12 - 18	34	483	116	499	411	650	361	2,554
18 - 24	43	263	40	379	449	797	228	2,199
24 - 30	22	490	98	810	240	2,873	267	4,800
30 - 36	20	747	187	1,013	635	2,670	584	5,856
36 - 42	24	166	36	815	269	1,633	170	3,113
42 - 48	1	13	3	7	10	11	8	53
Total	386	2,870	710	3,935	2,670	9,125	1,975	21,671
Type as percentage of whole total	2	13	3	18	12	41	11	100

Jaong X/1: Relationship Between Slag Category and Stratigraphy by Weight (to nearest pound)

Depth (inches)	Type							Total
	(a) "Tulang Mawasa"	(b) Fingers	(c) Droplets	(d) Multifingers	(e) Flat-Faced	(f) Irregular	(g) Cakes	
0 - 6	2	4	1	4	6	3	4	24
6 - 12	2	6	1	5	7	5	3	29
12 - 18	1	5	1	9	8	6	5	35
18 - 24	1	4	1	8	10	13	6	43
24 - 30	X	4	1	12	5	27	5	54
30 - 36	X	7	1	11	7	20	17	63
36 - 42	X	3	X	12	4	15	3	37
42 - 48	X	X	X	X	X	X	1	1
Total	6	33	6	61	47	89	44	286

Re-arranging the two previous tables by weight frequencies and comparing the results from eachŋ we getn

Jaong X/1: Slag Type Frequencies As Percentages of Total

Code	Category	By Count: Number of Pieces	%	By Weight: In Nearest Pound	%	Weight Frequency Rating
f.	Irregular	9,125	41	89	31	1
d.	Multifingers	3,935	18	61	21	2
b.	Fingers	2,870	13	33	12	5
e.	Flat-faced	2,670	12	47	17	3
g.	Cakes	1,975	11	44	15	4
c.	Droplets	710	3	6	2	6
a.	"Tulang Mawas"	386	2	6	2	7
Total		21,671	100	286	100	

Cakes are, almost by definition, the heaviest per piece, droplets naturally the lightestn The overall piece weight factors can be very crudely put in this wayn

Jaong: Pieces per Pound Weight (all approximate)

Category (rated by size)		Average	Maximum	Minimum	Range
g.	Cakes	45	55	(1-)	55+
e.	Flatnfaced	57	91	45	46
a.	"Tulang Mawas"	64	88	32	56
d.	Multifingers	64	92	43	49
b.	Fingers	87	123	55	68
f.	Irregulars	103	100?	*ca.* 40	(60)
e.	Droplets	118	150+	40	110+

There is thus a wide rangenof size variation within any one category, though on average cakes are largest, rather naturally (see further below), averaging about 3 to the ounce but sometimes weighing several pounds; while droplets average lightest at 8 to the ounce, but vary more than any other category. So many other factors effect size--for instance, how slag was run or hammered out of the "bloom"--that too much attention must not go that way. But there is a distinct, perhaps significant tendency for the size (weight) of three categories to *decrease* by depth; this deserves some attene tion, although it must be emphasized as no more than a suggestive tendency in one placee

Jaongę X/1: Relationship Between Depth and Slag Pieces per Pound

Depth (inches)	Type as pieces per lb. at this depth		
	(d) Multifingers	(b) Fingers	(e) Flatefaced
0 - 6	49	70	46
6 - 12	43	70	55
12 - 18	55	97	51
18 - 24	47	66	45
24 - 30	67	123	48
30 - 36	92	107	91
36 - 42	74	55	70

The relatively small size of flat-faced and multifinger pieces below 30" is rather striking. This is the *opposite to what might be "expected"* if the deposition of the slag was random or if it had been dumped. It is more consistent with smaller outflows of cooling metal penetrating and impregnating deeper down than the larger surfaced ones. This is in any case confirmation that concentrations such as these do reflect a genuine "on-the-spot" industry, they are not casual *cumuli* of slag.[3]

The study sample based on one Jaong trench, X/1, is no more than just that. To test the system a little furthere-despite the high effort involvede-the category counts were re-run at X/2, another 2½ square foot trench adjacent to X/1, but visibly a little different along the excavation facee some conspicuous large cakesę and some unusual pale discoloration here. Broadly, the X/2 results conformed to X/1, within the wide limits of variation found throughout all these open sites in almost every minor respect.

To give an impression of what this sort of excavation face looks likeę here is a 1966 field descriptione

Visual description of trench X/2 at Jaong.

The trench is 5' wide, 6" broad, and was dug to a depth of 48"a The trench tilts from north to south so that layers tend to descend as they approach the southern edge of the trench.

0" - 10":
a zone of black humus soil, loosely packed and with plant and other organic material interspersed, with quantities of iron slag, black and floating loosely in the soil.

10" - 12":
there is an abrupt change to heavily impacted burned orange sand, with slag tightly locked into the sand rather than disatributed loosely in the soil as in the 0 - 10" layera The color ranges from low intensity yellow through dark orange, pockets show as charred black or dark purple against the surrounding orange sanda

12" - 14":
a band of black soil with large quantities of iron slag; none of the burned and impacted qualities of the 10-12" layera

14" - 19":
burned sand ranging from yellow through orange to dark orange, slag is packed tightly into the sand.

20" - 21":
a distinct band of loose yellow sanda

21" - 29":
compressed burned sand studded with slag, color ranges from yellow through dark orange, and gives a conspicuous look.

29" - 39":
dark brown sandy soil with visible "chunks" of slag and other materiala

39" levela a large boulder extends for 27" exposed along the face now, its surface heavily discoloured; small particles of slag fused on upper surface.

39" - 38":
the soil is very light brown and sandy, and extends down to bed rock, as the boulder takes over the whole base. (S.O'C. 15.6.66).

At X/2, for reasons of economy in effort, only 24" were fully sampled: those that "looked markedly different" from S/1; that is, the layers of 24-30" and 36-42". Comparing the *same* layers (only) to X/1, and bearing in mind the gross totals for X/1 given in the base table at the start of this chapter (page 42), we get:

Jaong, X/1 cf. X/2, 24-30" and 36-42", Slag Compared
(numbers of pieces as percentages)

	X/2	X/1	Cf. Total X/1 (all layers)
a. "Tulang Mawas"	1	1	2
b. Fingers	2	8	13
c. Droplets	1	2	3
d. Multifingers	19	20	18
e. Flat-faced	6	6	12
f. Irregular	56	56	41
g. Cakes	15	5	11
	100	100	100
Total Sample (pieces)	9,813	7,913	21,671

The similarities between the two samples are striking, when one considers all the variables there are in the delta sites, even from foot to foot. This of itself implies that the categories have a reasonable authenticity when applied in this limited way. The significant differences are the smaller proportion of fingers in X/2 and the notably larger number of cakes. In both cases, these results are partly due to concentrations at the deeper of the two test levels in X/2.

Jaong, X/2: Two Slag Types Compared by Depth,
As Percent of All Types in the Layer

	24 - 30"	36 - 42"
b. Fingers	1.7%	4.3%
g. Cakes	9.5%	30.0%

But, as a previous table shows, fingers tend to be lighter lower. Cake does not vary as much, and this concentration is distinctly significant, though hardly surprising (see further at II.10 following)n

(d) Comparison with Buah: Big Slags

From the base study at Jaong, slag from the other main sites were critically examined, though exhaustive analyses by count were not carried through. In general, it seemed clear that the shape patterns were broadly the same with some important qualificationsn

In the big depth concentrations at Buah, the slag ran broadly to Jaong formn But at the ceramic-rich, slag-poor sectors (e.g., 66/E series 60 feet away from the slag concentration), an exceptional number of *very large* pieces of slag --*not* caked (i.e., Jaong category Cake) but clear, dark blackish or brownn-were strikingly visible on the drying tables; the largest pieces weighed nearly half a pound. Something "different" was going on just here at Buahn Similar patches of heavy and large slag pieces, including some large irregular lumps, have been found at Bongkisam, particularly close to the creek and at the lower end of the brook that flows down from Bukit Maras also.

The shapes of this slag are those already categorizedn, but each tends to be magnified. Though the larger of these from Buah fall within the preceding Jaong series, for each main category Buah runs twice (flat-faced) to seven times (multifinger) as large as anything normal in Jaong.

(e) Bongkisam Comparisonn "Chunks"

The other and most distinctive variant of the slag was noticed first back where this study began, on the outskirts of Santubong, past the end of the bridge over the creek to Bongkisam. Here pieces of slag are seasonally conspicuous *at surface* over a wide area, and at some points occur in large dark chunks weathered out by heavy rain and by the village ducks paddling down the mudn

These chunks do occur in Buah and Jaong, mostly outside the main slag concentrations--for instance, at Buah 90 yards back at the foot of the hill. In one place at Jaong there are several on the crest of the hillock behind the Batu Gambar rock figuren But nowhere else have they been located densely and solidly, as at the downhill slope of Bongkisam over almost to the bank of the main Sarawak River. In a matternof minutes one can find a piece of this sort weighing 3-4 lbs., 4-7" x 7-9", and up to 2-3" thick, sometimes more. Moreover, in July 1966, a number of such pieces were excavated close to the Bongkisam shrine II (at Z/A1), four large examples together weighing 10½ lbs. This is unlike any pattern from the other sites.

These chunks are made up of a tangled mass of hard slag-like iron (usually very dark and extra-hard), mixed with burned earth or clay and other matter, to give the look of a fossilized sponge or some other marine rather than man-made unitn The whole, whether clearly metallic or not, has cooled and fused into a rock-like solid, *not* susceptible to chipping or breaking as are the "cakes" previously discussed. Nor are the constituent pieces necessarily consistent with the rest of the typology previously given. The form suggests either a broad-based firing of ore in the open, or the failure to separate bloom, or some other ineffective end-process.

At the same time, these chunks constitute only a very small fraction of the Bongkisam slag,nmost of which conforms to the Jaong classification.

II.10. WHAT DO SLAG FORMS AND NUMBERS MEAN IN TERMS OF PROCESS?

At this early stage, it is easier to pose the above question than to answer it. The crying need is for comparative material from other places--and indeed even relevant observation at the ethnological level in "primitive industries." The advantage of persisting with this approach--or some development from it--is that it has reduced the mass of slag from a mess into something nearer elementary sense. And although this approach cannot very well be called easy, it can be used on the spot, in the field, as a form of preliminary, crude analysis. That is, alas, about the only analysis the slag is likely to get as research facilities and related interests stand in Malaysia and Southeast Asia generally at this time. Something is better than nothing.

(a) Slag Shapes as Process Pointers

From what has gone before it looks as if a large part of the slag at Jaong--and by interpolation elsewhere--was tapped off furnace, oven, or kiln, in a fairly well-controlled way. The occurrence of large slag pieces at Buah and in really big chunks at Bongkisam may well indicate either more massive or differing operations there. It is logical to deduce that large slags result from a more intensive or skillful (or both) reduction of the ore, such as might reasonably be expected in an industry enduring over centuries in the same locale. Such improvements amount to an inflection of emphasis rather than any fundamental change of process. A somewhat similar inflection is the slight change in cylinder size from Jaong to Bongkisam (III.15). On the other hand, there is always the possibility that more big slag derived from use of inferior ores, as the easy and accessible ones were more and more exploited. There are other possibilities, which seem too hypothetical to be worth including here.

Whatever went on, some of these slag form categories must directly represent outflow by tapping or overflow from an edge, particularly finger and multifinger, and marginally droplets. These forms initially suggest a more or less *vertical* down-flow. On the other hand, flat-faced can hardly have been formed in this way; this looks as if deposited horizontally, for instance on the bottom of a hearth, perhaps as part of a puddle of "bloom" from which it could be separated by hammering (rather than separate tapping off). Again, multifinger gives the feeling of production close to a center of intense heat, whereas droplets suggest a more marginal cooling, not so close to the heart of the fire. Fingers imply a more rapid run-off, on a narrow front, then multifingers--though the overlap of these vivid categories must be emphasized once more as we write this. And, of course, merging fingers can make multifingers, just as tip falls from fingers can make droplets. "Tuland Mawas," the elbowed sort, although often far from clear-cut, on aggregate gives the impression of flow around a curve or over a groove. Four out of five of these categories consist primarily of pieces which have cooled in positions where they were probably formed *downward* or on an incline. The rest suggest a less discriminate spilling over or run out. This reaches the extreme with cake, which takes us beyond simple slag into the environs of its by-production. Cake is slag plus. The plus consists of cinder, burned clay, and other matter. Here is an on-the-spot description of the largest cake from Jaong X/2, which (as we have seen in II.9) is notably cake-rich. This is one of the biggest cakes ever excavated in the delta:

> Sand cake from Jaong trench X/2. The piece at its greatest length is 11 cm., it is 6 cm. wide and its highest elevation is 5.5 cm.
>
> Sand is massed tightly around the slag, apparently adhesion occurring under intense heat. While the cake is hard and compressed, grains of sand can be rubbed from the surface with ease. The cake is easily fractured by a sharp blow.
>
> The colour is predominantly a dull orange, flecked with black pieces of slag and scorched black chambers in the block where molten slag has charred the sand. In many areas there are thin walls or veins of slag. The slag is these veins is usually a glossy black from a high degree of carbonisation. Frequently these thin shells of slag exhibit a cellular arrangement as if the slag formed around a number of air bubbles.
>
> These cakes also contain slag pieces in the shapes and sizes normally encountered in slag that is *not* in a sand matrix. There is an essential difference, however, in that there are firing chips of slag in the sand cakes that are not met with elsewhere. (S.O'C., 4.7.66)

Cake is more numerous deeper, though irregularly, as befits a basically "base line" deposition. It evidently represents the admixture of slag with surrounding substances in a way which indicates the bottom or wall of a specific hearth. It is difficult to go much beyond that until one can find a site where it is possible to recover, separate out, and analyze the whole structure of the prehistoric operation and its constituent parts. This is unlikely to be achieved archaeologically--unless by real luck--in any open site which has in the first place been intensively used and frequented over and over again through a considerable time-span; and in the second place has subsequently been exposed to prolonged major disturbance from tropical climate, root and animal actions, then later from human planting, digging, etc. A more peaty soil, perhaps submerged in a saline water-table, might help in this--and could preserve wood, bone, and other evidence totally lacking in the delta sites. Kota Batu, the ancient capital of Brunei, is such a site--although preliminary excavation there showed no direct evidence of iron-working (T. and B. Harrisson, 1958).

Let us wind up this part of the discussion by once more quoting from an old delta workbook. In 1952 one early attempt was made to put the problem slag-wise:

> It seems that only by a lot of patience and a bit of luck can one clear up the who-how-why of slag. We have still to find any trace of a true forge or kiln proper. If the stuff were dumped, the presence far-off the creek edge (and even up to trench G on the hilltop) is too weird. Action is therefore to continue hill tests, watch out in all trenches for kiln and other indications; and persevere with patience.
>
> (T.H., V: 225; 14.7.52)

This has been done. But still no kiln, forge, or real proof of exactly *how* this industry was run in detail. Yet the slag forms spell out a prehistoric process: if only we could read their whispers.

(b) <u>The Slag as a General Indicator for Smelting Methods</u>

The delta slag is primarily the residue of smelting operations producing wrought iron from ore. Further refinement by the crucible process to get steel would not produce anything like the same amount of slag, though allowance must be made for this as a source, as also for some small amount resulting from any third stage of making tooks from the steel (for which there is, however, little evidence here; cf. V.26).

The deposition and the morphology of this slag, at one end of the scale in multifinger, finger, and droplet; at the other in cakes, rather suggests a largish, *open* hearth system of smelting rather than any elaborate, enclosed kiln or oven. No trace of any firm walls or chambered units has been indicated in all the years of excavation. Conditions militate against recovering such friable structures centuries later in an open-disturbed tropical site--and this difficulty has constantly arisen under much less unfavorable conditions in temperate archaeological sites, also. Even so, one ought by now to have expected *some trace* of just one such structure to have by chance survived in Bongkisam, or Buah, or Jaong, where so many cylinders--of possibly about equal friability--have been recovered, for instance. Nor are there any vertical markers or runs in the excavated or exposed faces which cast even a faint shadow of this kind. There are, on the other hand, plenty of messes and massses and mushs of caked iron slag and clay, as described for Jaong X/2 in the preceding section. That is *not* to say that there are no patterns at all, particularly in the horizontal. It is only that these are extremely confused, not just from later disturbance by tree roots, burrowing animals (which abound), and historical human activity, but by what can only be active "disturbance"--in the sense of vigorous, varied, vertical probes and pushes--at the time of the main site occupations. Although this broad pattern has taken many forms, this is a summary of what might be called the delta "norm" so far as positive archaeological materials are concerned:

1. *Under* the surface, below a *natural* topsoil layer which may also contain some loose slag (usually then clean, bleached, rain washed).

2. One or more layers of heavily impacted soil, often burned in color, packed hard, sometimes requiring force to open up for properly layered excavation. Largely smelting relics, but never exclusively so (except perhaps at Temakul as above?).

3. Beneath 2, there is normally a zone of heavily heat-affected sand or other soil, which does not necessarily contain large quantities of slag.

4. Underlying this, native rock or sterile sand--if the former maybe with pieces encrusted on the rock surface (V.27).

The 1-3 sequence may be repeated several times over or in any re-order before reaching 4. More usually, however, 2 *is repeated in a series of "shelves,"* compacted and crushed downwards--clearly the result of *sequences of firing* on the same position.

We believe--after very thorough study of the literature both for iron age archaeology (mainly European) and for metallurgy--that most of the visible "shelves" or lines represent the *bottom* or trough of shallow bowl-shaped hearths, made from local materials. To operate this way with success, keep the temperature sufficiently high for ore-reduction, it was of great help to have large quantities of high quality fuel readily available. The charcoal obtained from mangrove, dominant wood of the delta, is unbeatable for this purpose: its abundance was surely a prime reason for doing the smelting in these otherwise "unlikely" places and made it economical to do so (cf. III.18 on fuels).

Iron presented this high temperature problem for the first time in Southeast Asia. The "earlier" metals of the area could all be handled at much lower temperatures:

Metal	Melting Point (°C)	Minimum Smelting Temperature (°C)
Gold	1063	Just melt it (no problem)
Copper (for "bronze age")	1083	400
Iron	1540	800+ (see below)

At 800°, of course, the pure iron in the ore is *not* melted; what comes off is the rest of it, as slag. This big difference in melt-smelt levels was one reason for the late development of iron technology. But more important is the fact that iron occurs in oxides which are difficult to reduce: that is to detach the iron from the oxygen in the oxide. The reject slag is largely a compound from iron oxide and silica (sand). To get this compound, so that it can be separated from the iron in liquid form, the 800° minimum smelting temperature needs to be effectively exceeded, lifted to around 1150°. This produces iron in a malleable, usually spongy state (the "bloom"); the slag can at least be partially drained away as liquid and the rest separated by hammering before it cools back into solid shape.

(c) The Bowl-Hearth or Furnace

The whole question of the evolution of iron smelting in early times has been the source of long, sometimes heated controversy, and this remains unsettled in detail. But in so far as there is a consensus, it is towards the view that some kind of bowl-hearth was widely the basic style. R. F. Tylecote sums up succinctly:

> We have no means of knowing how the primitive bowl-hearths were covered, if in fact they were covered. The only two hearths found [in Britain] suggest that they were *not*. (185)

It has been experimentally demonstrated that a cover much increases iron recovery, but this need not at a pinch be any more than a layer of charcoal-dust. A hearth of only 9 inches in diameter requires 2.5 cubic feet of air blown into the fuel each minute, an amount readily supplied by a small bellows and easily exceeded by the hollow-log and bamboo pipe bellows which has persisted in use throughout Borneo and Southeast Asia, as well as Madagascar (cf. VI.35-36). Tylecote has described the work of Wynne and others in this field in Britain, and in America the process has recently been reviewed by V. B. Proudfoot who summarizes the situation:

> Simple bowl furnace was reconstructed to investigate the technique and efficiency of early iron furnace. 20 per cent efficiency was achieved by calcining (i.e., roasting) the ore for some hours at 800°C. in an oxidizing atmosphere and then carefully pre-packing the ore in the hearth on the charcoal fragments, which when burning producing a reducive atmosphere of carbon monoxide with air entering through the tuyere. This pre-packing technique yielded readily separated compacted mass of iron.[2]

This is the *sort* of process that probably was favored round Santubong. The slag could be tapped off in a variety of ways--most simply into little concave hollows scooped in sand before the hearth. The *amount* of slag produced by such methods experimentally came out approximately thus: the weight of slag and reduced ore totaled *more than twice that of the usable iron*. H. H. Coghlan, who has a lucid chapter (40) on early smelting, cites a case where a charge of 300 lbs. ore fired with 200 lbs. charcoal produced 25 lbs. of iron. Although lower than some Asian results recorded in historic times (cf. Part VI), we think this could have been "economic" in Southwest Borneo.

Many possible variations on these procedures are known and it is better than possible that other unknown variants were developed in the delta and have now been lost.

In interpreting all this it is necessary to rely largely on European examples. For, as Coghlan (86) observes:

> To follow the evolution of the iron-smelting furnace is a difficult matter. First, the number of iron furnaces which have been found and excavated is not very great; also it is exceedingly unfortunate that evidence from the Ancient Near East is scarce and far from satisfactory. No doubt thenNear East contains the cradle of the earliest iron-working and a type series of smelting furnaces from these lands would be of the highest value. Unfortunately, so far such evidence is lackingn

The same author emphasizes another difficulty: that the known prehistoric furnaces even within Europe "represent a confusing number of types."

Unfortunately, as well as the paucity of good data from the western side of Asia, that from the eastern side--where so much good archaeology is now being done--is seldom relevant, because they developed a special line of iron technology towards "cast iron" long before the Jaong period; and this can seldom directly illuminate our present problem.n[3] As is not infrequently the case when facing up to Southeast Asian puzzles of prehistory, some of the best help comes from interpolation through ethnology. To anticipate later data on this theme a short extract from a description of the nineteenth century iron industry at Mtn Popa in Burma written by Dr. Chhibber, a geologist:

> A furnace simply consisted of a sort of circular or oval pit, three to four feet in diameter, dug in compact earth in certain raised portions of the ground, e.g., the bank of a streamn The pit was connected with a circular hole above, a little more than a foot in diameter, through which the smelters subsequently added supplies of charcoal . . . (they) arranged alternate layers of charcoal and iron out in the pit. After igniting the charcoal they closed the mouth of the pit by means of earth.n[4]

This sort of set-up, locally modified in space and time, could have been the basis of much in the delta operations. We come back, in Borneo, to some fairly simple bowl depresn sion or shallow pit shaped right there out on the creek banks, roughly lined with swamp mud reinforced with pebble perhaps (cf. V.28.b); the ore and fuel to form a loose cone or low pyramid, tamped down with charcoal dust, or earth, even evergreen leafy branches of the mangrove trees all around.

For an ethnographic example, much nearer home, see what Sir Spenser St. John, the most acnurate of the early English travelers in Borneo saw among the Kayans of the Baram River, 350 miles northeast of Santubong in 1851 A.D. These Kayans have been the finest craftsmen of steel in historic times (we shall meet them again in that habit, at VI.36)t This is how simply they proceeded to acquire their raw material:

> Their iron ore appears to easily meltedt They dig a small pit in the ground; in the bottom are various holes, through which are driven currents of air by very primitive bellows. Charcoal is thrown in; then the ore, well broken up, is added and covered with charcoal; fresh ore and fresh fuel, in alternate layers, till the furnace is filled. A light is then put to the mass through a hole below, and, the wind being driven in, the process is soon completed.t[5]

Clearly, this is something of an oversimple process unless ore and other conditions are almost ideal far inlandt The delta's internal operation and external contact gave much scope for refinements and innovations, lost todayt In particular, from the present point of view, the morphology of some delta slag suggests methods of tapping it off in advance of those known in some available prototypes. For the matter of that, there is no need to postulate close uniformityt it would not be atsurprise if quite other hearth or furnace forms were in use in this area at one place or another at one time or another inside the 700-1350 A.D. frameworkt Further speculation is out of place when we still know so little of exactly what did occur in detailt

But when all is said and done, and after allowing for great distance, Coghlan's general account of the "bowl furnace" of the early Western iron-age will serve pretty well here:

> For iron smelting the bowl furnace was simple and widely used. As the name indicates, it consisted of a bowl-shaped hole in the ground, lined with clay which baked to a hard and fairly smooth surface. Artificial draught would appear to be necessary with this type of furnace and was probably provided by means of a bellows and blast-nozzle or tuyeret The charge of fuel and ore would be built up in the form of a cone, or dome, above the level of the top of the bowl, while the pipe leading from the bellows to the blast nozzle would pass over the rim of the bowl as indicated by Neuburger for the Kordofan bloomeries. It is by no means certain that this somewhat awkward arrangement of leading in the blast air over the rim of the bowl was the method most generally employed; the air-supply could have been introduced at a lower level with advantage. It is also doubtful whether means for tapping the slag were used in connexion with the early bowl furnaces. (88)

In Borneo, the blast air almost certainly did not follow the "awkward arrangement" above described. Something better seems to have been done with the slag, too. But it is enough to settle for this general picture of the bowl furnace (with frills) at this stage.

If, meanwhile, there seem to be world-wide features in common for some of the smelting process as examined in this part (II), we must now enter an area of prehistoric metallurgy where the analogies appear to be more limited and the peculiarities more defined--the area of "crucible" use (III). Before "crucible," however, one other interesting aspect of slag remains: its "non-functional" significance, so to speak.

II.11. SLAG SCATTER PATTERNS

The Sarawak River delta sites which have been most fully excavated and therefore more fully reported upon--including both our three main iron sites and others--fall into two main categories as regards iron slag:

(i) Sites or parts of sites with every evidence of some form of massive iron working in terms of residual slag at Buah, part of Jaong and at several points near Bongkisam--with maximum concentration at Buah as regards depth and at Jaong as regards well-spread shallower concentration, but at Bongkisam perhaps as regards gross bulk. (A "*concentration*" may be taken for delta purposes as over 50 lbs. per surface square foot, and a major concentration as over 100 lbs; see table on page 49).

(ii) Places of all sorts--and sometimes surprisingly placed--where slag is scattered about (normally not visible near the surface) on such a scale as to be unquestioned evidence of past human activity; that is, ignoring the very few places in this terrain where slag (which is of course heavy) could have been flooded, washed or eroded into the present position, without direct human agency; note here the absence of slag, despite abundant wave-washed ceramics on the Kra islet close to Santubong (I.3.d.ix).

Slag *scatter* spreads over more than 250,000 square feet of known, explored, dry delta land.t[1]

In this respect, the *scatter* areas are in this way as impressive and in some ways more puzzling than the concentrations. For the countryside is metaphorically littered with the stuff. And the delta scatter-pattern itself is only part of a wider one, where slag is found at many points further inland and indeed up into the hills and uplands of the Sarawak River headwaters and across the interior. One should not perhaps distinguish *too* sharply between concentrations and scatters; the former tend to be surrounded by the latter; the differences are then largely of degree. But the scatter ranges out into the most "unlikely" corners, away from any concentrations. Such scatters might reflect anything from minor re-working through to no working at all.

The absence of a concentration does not, therefore, mean the absence of *any* iron-working. The presence of concentration (as here defined) indicates such activity on a better than casual scale--certainly more than a "one shot, one burn" basis. But some of the thinner outlying scatter sectorsn, down to bits of slag a mile out from the Jaong concentration, are insufficient to prove any actual work producing slag at that spot at any time. Moreover, these slag pieces are not distinctive. They do not fall outside our main delta site categories (IIn9). They do not suggest any other, separate isolated special procedures.

Scattered slag may be at the level of one small piece every few yardsn Even at less than 1 lb. per surface square foot, one can meet slag pieces regularly--for instance, *very much more frequently* (10,000 x times) than beads in the delta sites. But with only one *piece* every few yards the presence of the stuff would still remain noteworthy and significant in prehistoric times (and there is, in this case, no question of the slag being "later")n Met with in remote points of the Sibu Laut swamp, up the Sematan creek, far across the bay, in Sungei Jerai beyond Bako or on the Bukit Maras hillsiden, the final impresnion is every bit as strong and thought-provoking as for the 180 lbs. per surface square foot belt of Buah or Jaongn It is as if it had rained *tai besi*, those iron droppings (cf. II.5) once upon a distant time. all across skies already loaded with their own 100+ annual inches of (wet) rain.

Wherever the pieces of slag are too heavy or so positioned as to be incapable of reaching them normally by non-human means, every single piece upon a hill top, rock edge, or mud patch needs explaining in some kind of humannterms.

What, then, accounts for this scatter past the degree of possible minor working or even single incidents of individual slag "finds"?

One idea only has stood up to the tests of re-checking by excavation, time and discusnion. Put in a crucible, it is the belief that slag played a part in ancient native belief: that it was in those early metal days after the stone age a sacred iron, a thing of magicn Time and widened knowledge damped some of the ardor in that sacred flame. Yet the warmth survives today in folklore, and vividly in the role given to the blacksmith in many Borneo and other Southeast Asian communities--though as there is not one single practicing smith in the delta today, we cannot check this out in the identical habitat.

II.12. THE MAGIC IRON

(a) Hypothesis

Any attempt to reconstruct--let alone interpret--a culture complex (such as that of over 600 years ago with which we are here concerned) cannot afford to limit thinking solely to material techniques and tangible results. Of almost if not entirely the same importance before 1400 A.D. were the less obviously "economic" but intimately integrated activities of the mind. The smelter or smith was a man of his time, plunged as deeply into the psychological feel of souls and spirits as in physical work with stone and steel and sweat. Thus, in this instance, a single piece of slag lonely now upon an unlikely rock on Santubong Mountain can be as revealing as any great agglomeration in the D/sector at Buah.

It is our view that the distribution of this slag has to be interpreted at two levels. *One:* the concentrated masses of it, and many lesser deposits, are the direct result of working iron ores and to a lesser extent refining wrought iron, possibly even to a small extent reworking steel (cf. III). *Two:* the immense web of thinly scattered pieces--barely indicated in our general survey of slag distribution (II.6)--reflects another kind of activity, in which slag was treated as something of merit in its own (mystical? magical? spiritual? fanciful? funny even?) right. Of course, it is even more difficult to reconstruct--let alone interpret--level two than level one. But it would be wrong to ignore it. For there it is, in the archaeological evidence, underground, palpably not the result of recent or of inhuman sponsorship. This isolated treatment of slag away from the actual iron-working set-ups is, we provisionally suggest, in part due to magical and related beliefs. For convenience we can therefore term it, without prejudice, "the Magic Slag." In that sense, too, the present day delta Moslem population see it, a little more crudely, as heavenly faeces (II.5). Islam came into West Borneo after Bongkisam smelting had phased right out. The pre-Moslem people who continue as the main population of the whole island inland, had more earthy views. As late as 1833 George Windsor Earl, one of the better English writers on Borneo in the previous century, noted:

> the iron which is obtained in the interior is said to be valued by many of the wilder Dayaks even more than gold.[1]

But it goes much further and deeper than that, into the very bowels of Dayak protohistory and faith. As the slag is to the ore, so recent belief is to ancient reverence. Let us illustrate this theme with only two examples (much abbreviated) from West Borneo peoples, the Dusuns of Sabah, and the Sea Dayaks (Ibans) of Sarawak, two "races" who have no physical contact, live in wholly different environments and are in brief about an unlike each other as can be in Southeast Asia where prehistoric basic likeness underlies modern diversity.

(b) Illustration

First, take the Sabah hill peoples studied by I. H. N. Evans (1953)--one of the best but least recognized scholars of Malaysia (cf. also VI.33)--in his "The Religion of the Tempasuk Dusuns of North Borneo,"[1] from which the following is much condensed (his Chapters I and IX).[2]

These Dusuns look to a supreme male and a female deity, siblings who emerged from a rock. The female made the earth, molding it with a weaver's sword. The male made the sky "with iron ribs" (p. 17) and took charge of all spiritual affairs. By joint efforts, the pair made men and women, but he was solely responsible for making food, including rice, coconuts, sugar-cane, betel-nut. This good provider was named Kinorohingan, "who is a smith" (p. 16); he "now lives in the seventh heaven," spending much of his time asleep--to wake him "strike him on the head with a hammer" (p. 16). There are seven heavens in this theology, just as seven souls associate with each living Dusun. One of these seven is permanently seconded upward to Kinorohingan; a second in the living frame joins the first in death, in heaven. This is another vital function of Konorohingan: "the welding--again the blacksmith--of the human soul that goes up to him when a person dies with that soul of the same person that is already in heaven" (p. 17). Moreover: "At intervals these combined souls become worn-out, and Kinorohingan reforges them" (p. 70). Eventually the souls are exhausted and then "he makes them into winds," and keep them in a hole in a hill (p. 70). Kinorohingan has an alternative name--common form among Bornean "deities"--which is Minodsupuk, "from his making the slag in his capacity of blacksmith (*modsusupuk*)" (p. 19).

Compare these fundamental beliefs among hill people in the interior of North Borneo (now Sabah) with those of the most numerous of the sub-coastal peoples far to the south in Sarawak. The Iban Sea Dayaks have a more elaborate spirit hierarchy--largely preserved because their own native system of writing and genealogies has survived to codify the basic folklore.[3] One of the largest elements in their complex intellectual belief is Selampandai--alternative name Selampetoh.

Selampandai is one of the seven godly siblings in the "Top Family" who brought a new way of life to the Dayaks. These seven, six brothers and a sister, did not begin *mankind*: that originated in a vague overall deity, Bunsu Petara, who when decentralized his detailed responsibilities, thus:

THE TOP FAMILY OF THE SEA DAYAKS

- SENGALANG BURONG (G/2) (the Brahminy kite "god of war")
- SIMPULANG GANA (G/4) ("earth god of harvest")
- SELAMPANDAI ("maker of man and god of iron")
- MENJAYA MANANG RAJA (chief male shaman)
- RAJA BIKKU BUNSU PETARA ("priest to Almighty God")
- ANDA MARA ("god of wealth")
- *INI INEE* (spinster; greatest doctor)

Selampandai is involved in (and invoked for) every Dayak activity to do with metal, as well as being responsible for the fundamental welfare of men--especially men in *good* health. His symbol is the bellows forge and in the "script" on the writing boards (*papan turai*) he is represented as a pair of hollow tree trunks each with a wind pump in the top. In the enormously elaborate Dayak chants this approach is signaled by the puffing sound of bellows and clanking of hammers upon iron. Selampandai controls his own territory in the other world, the land of iron (*besi*). In the journey of the spirit proclaimed in the great chant of the Festival for the Sick (*Gawai Sakit*) the invisible traveler is adjured, at stage 22 of the trip according to the coded writing board

Leave that place
And come to a stone bellows with hole,
Blown by the feathers of the victorious cocks,
Then reach a hill with a holenblown by the wind,

Which murmurs along the *lalang* bamboo joints.
This is occupied by Selampandai,
Who can make the dead live again.
This is Selampandai's land,
He who forges the body with a clinking sound.

Or in the seasonal Farm Festival for the rice (*Gawai Umai*):

Reaching a hill overgrown with moss,
On a range covered with *lukut*,
This is the settlement of Selampetoh the excellent blacksmith,
Who comes from a swift stream over a waterfall.
This is the land of Selampandai creator of man,
Who comes from the Balai Nyabong range.

And triumphantly in the Festival of the Whetstones (*Gawai Batu*), which celebrates the excellence of the knife-sharpening stones (cf. V.28.j):

Reaching the edge of the white stone,
Like swords while sharpening.
Reaching the edge of the *anggong* stone,
Pressed by a piece of brass-inlaid iron.
This is occupied by Raja Jegedong,
Able to forge iron to make it last,
Extremely tough and very sharp.
It is occupied also by Raja Panggai,
Originator of letters and reader of the compass.

The *anggong* is a shaped stone, usually whetstone. Brass inlay of iron is the highest form of traditional tool-making in Borneo (VI.36-37; cf. damascene in III.19.b). Raja (or Merom) Panggai, whose alternative name is Raja Jegedong as above, is intimately mixed up with Selampandai, in all metal affairs, as he who introduced from *outside* (not as part of the indigenous hierarchy) the items mentioned in the text. His descendants intermarried with Dayaks, to produce:

1. MEROM PANGGAI
2. MEROM PANGGAH
3. ABANG MUSA
4. PATEH SIMPONG
5. PATEH REJAB
6. RAJA RENDAH

7. PATEH GURANG

8. PATEH IRI

9. PATEH TELIANG

10. PATEH AMBAU

11. NUNONG

12. CHAONG

13. TINDIN

14. Rinda (f)

15. KALANANG

16. TUAH

17. SEING

18. BUSU

19. UYUT

20. Pala (f)

21. KALANANG II

22. UYUT II

23. Penghulu LINGGIR

24. Umang (f)

25. UYUT III

26. Penghulu SANGGAT (borne 1925)

27. DIN (schoolboy, 1968)

This Dayak study has deduced on the basis of correlated genealogies and generations that Merom Panggai--who is referred to as a "Persian" and certainly "from the west" (according to this folklore)--existed at least symbolically "a century or more before 1350 A.D." The compass was developed directly in China out of magnetism in iron combined with Taoist geomancy and its concept of *chi*--harmonizing the tombs of the dead with the cosmos and everyday human life (the living and the spirits). By the Sung dynasty the compass was well established in use on ships, and as this usage spread it must have revolutionzed sailing across the South China Sea between Borneo and the mainland. In the West, however, the compass seems to first have been known in the twelfth century, at earliest a century or more behind China (cfn Joseph Needhan, 1962: 250).[4]

(c) Comparison

The similarities between Tempasuk Dusun and Sea Dayak are remarkable--and incidentally, no such parallels have been noticed before this. They even go down to detail, as the "hill with a hole blown by the wind" occupied by Selampandai able to make the dead live again, alongside Kinorohingan's disposal of the ultimately dead as wind kept in a hole in a hill. There are, too, parallels for outside Borneo, though hardly so exact. The Toradja hill people of Celebes, for instance, have a "subterranean smith-god, called Langkoda ('the lance') who tests the souls of the Toradjas as to their quality," while another "Smith of the Upper World" here also the Lord Creator, reforges the souls that have failed."[5] We could spread out to Vulcan--lame like Langkoda of Celebes; likewise Hephaistos who married Athene, and employed the Dactyloi to forge steel in the mountain fires, and was lamed by Zeus (his symbol the eagles)--or nearer home to Brahma in his blacksmith role. Or we may instead be satisfied with the popular Javanese story of the Majapahit empire (1294-1520 A.D.) in which Damar Wulan ("Radiance of the Moon") steals the magic weapon of Menak Djingga ("the Red Knight") and beheads this "limping, voluptuous and cruel person" with it. The precious weapon, famed and unique in Indonesian lore, was of "yellow iron" (Claire Holt, 1967: 276).[6] A distinguished ethno-geographer from Syracuse University has put it from another angle, which may suitably serve to conclude this small sample illustrating the mystical theme of so much early (and later) iron:

> Some agricultural societies in Southeast Asia evince a prejudice against mining, even of gold; they believe that the removal of ores offends the earth spirit. In other tribal religions, the earth is thought susceptible to desecration in other ways. The Baiga, a people of the Central Indian jungles who cultivate with the digging stick, consider the use of the iron-shod plow an abomination because it tears the breast of the earth mother. In the American Southwest, government agricultural advisors who tried to introduce early spring plowing among the Indians of Taos ran into a

> wall of hostility; the Taos believe that in spring the earth mother is pregnant and must be treated delicately. (David Sopher, 1967: 40)

What all this adds up to is, simply, there are profound feelings about iron among people who deal with it at first-hand from the ground up, and these are (or were until very recently) at their most pronounced in our area. Iron is part of the very essence of life, of the creation and sustaining of life, and equally of after-life and that undying human urge for immortality. Iron intellectually impregnates every corner of this belief as well as practically shaping everyday reality. Iron brought a fundamental, revolutionary change to the Dayaks and other peoples of this great rain-forested island. The blessing was so intense, and then the mastering of even quite advanced techniques so stimulating, that decent gratitude flowed into the tissues of an anthropomorphic universe, where earth meets sky and where repetition--whether of cropping rice or smelting success--takes a long time to dim the innate memory of what life was and could be like without such divinely helpful sustenance.

(d) Explanation

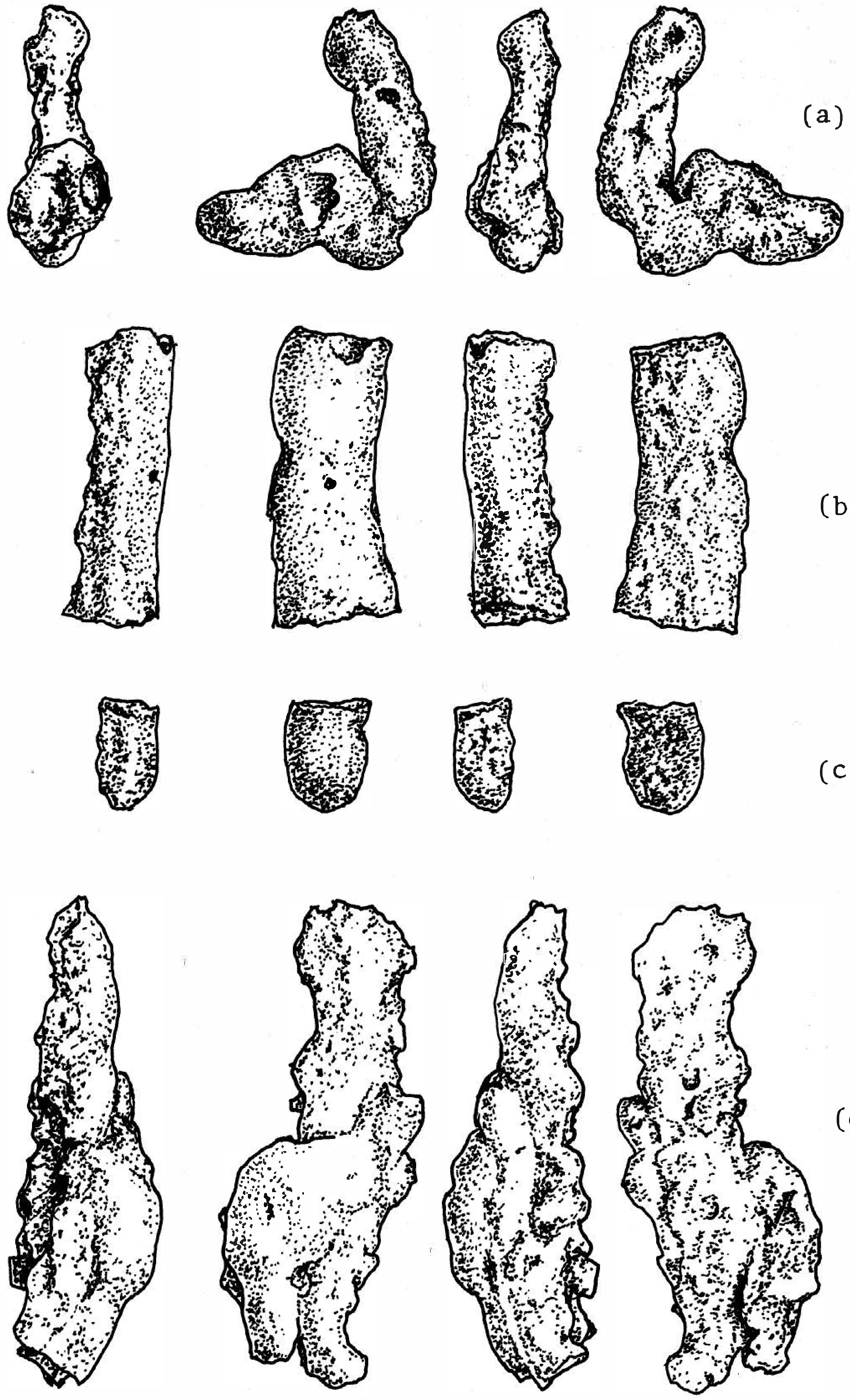
Iron was the greatest thing that ever came to Borneo. If one had to seek a modern comparison, the marvel of iron for prehistoric jungle-folk was something like that of landing on the moon to industrialized western man now. The process of modern industrialization, too, has made it easy to forget what an important, difficult, exciting business it once was to smelt ore out of your own piece of the earth and then make tools from it which for the first time gave adequate control of all that grew out of or moved over that earth. No wonder that a thousand years ago Borneans wondered and worshipped this tremendous boost for peasant morale. No wonder they anxiously worried lest anything upset each smelting effort--then wholly empirical, without benefit of chemistry.

This iron has left its mark all about the landscape of southwest Sarawak, as we have seen. To suppose that at every point where there are multifinger and other forms of clearly *tapped* slag *thus* there was also smelting would be to visualize cities of iron workers, in a setting where even a vivid imagination could barely go beyond extended settlements (e.g., potable water, even now severely short in the delta, alone was a size-limitation). To suppose that some of the more random, unrelated, inadequate pieces got there by another sort of human interest fits both the facts of typography and the fantasies of a faith which has now been briefly sketched--and which can only have been far more elaborate and vivid when experienced at first hand in the days before cannon, Islam, steam, and radio (in that order of appearance).

Melting this down to strictly delta terms, we consider that a significant part of the more widely, sparsely scattered slag represents some human disposal of this material, either in large-scale rites (comparable to, for example, contemporary turtle-egg battles of the *Semah* fertility ceremonies in Santubong Bay) or on a smaller scale as talismans, charms, stimulants and so on--in something the same way that individual sherds from old stoneware vessels were used in cave burials and related rites elsewhere in Borneo.[8]

This scattering, dropping, placing or hiding of slag pieces can be associated fairly loosely with the other evidences of religious and related observances in the delta: the rock carvings at Jaong, sometimes slag encrusted, the shrine at Bongkisam with golden *linga* in silver box, the wide scatter of beads and broken stonewares, curiously shaped stones, and earthenware "phallic tops" all over the place; and a good deal else which goes to show that the economy of iron was not simply technological and matter-of-fact.[9] An appreciable number of these things have incidentally a sexual or phallic quality worked in.

Extending this for a moment to other sites, it follows that small amounts of slag do not necessarily indicate ironworking on that exact spot. They certainly do point to it in the vicinity; and if at all frequent and dense over more than one spot, probably point to smelting. This could be either confusing or helpful to field investigators elsewhere.[10]



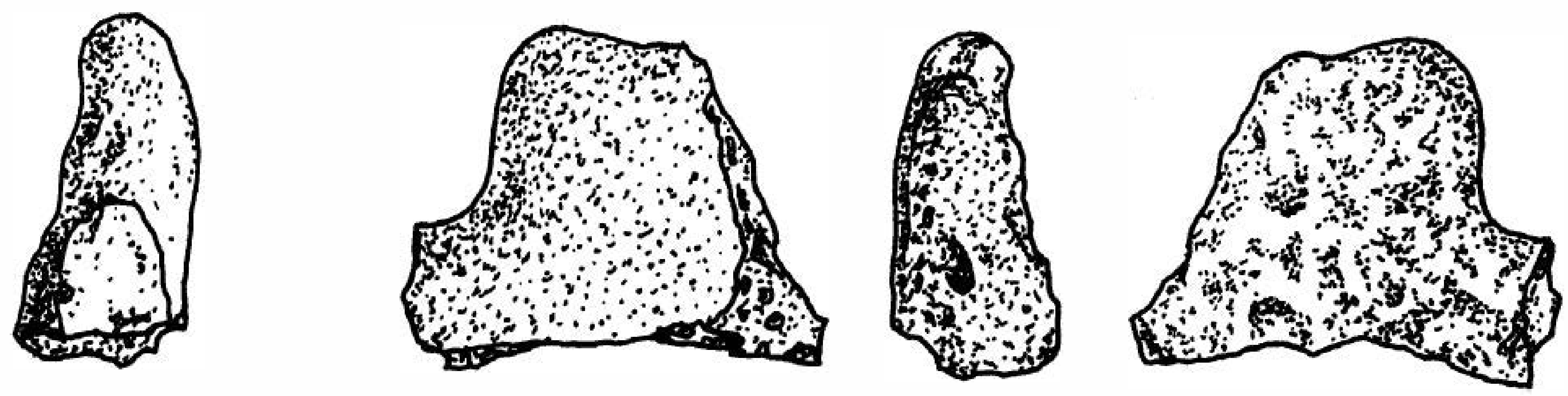
(a) "Ape Bone"

(b) Finger

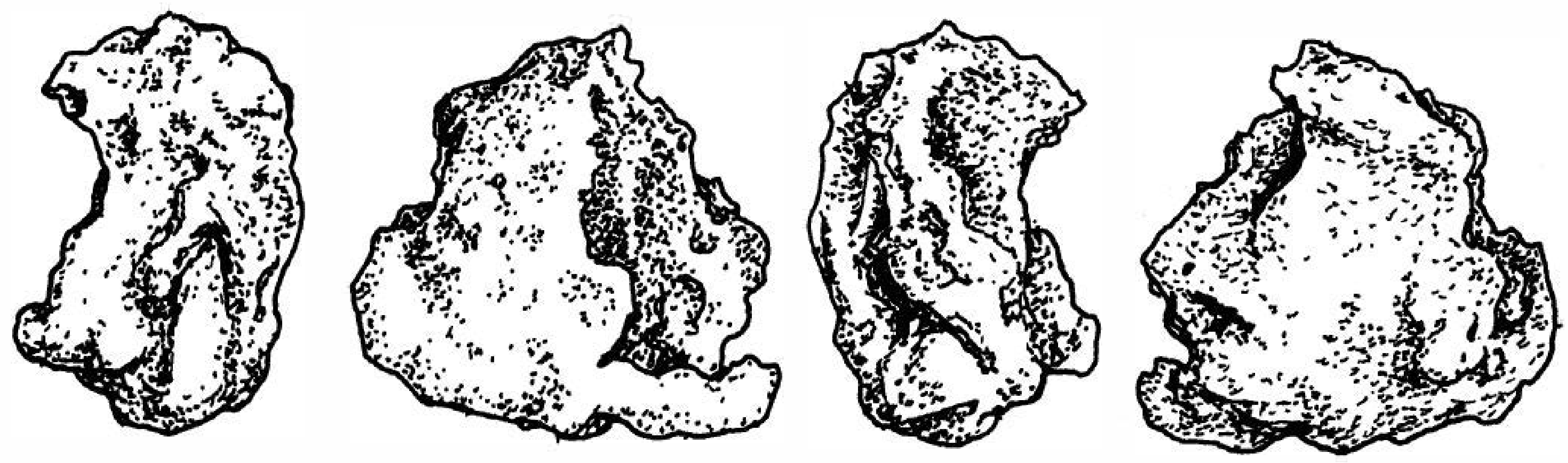
(c) Droplet

(d) Multi-Finger

Plate 3. Slag Series. Typical Pieces. Drawn in Frontal, Posterior and Lateral Views. Natural Size (Chapter II.9.b).



(e) Flat-face

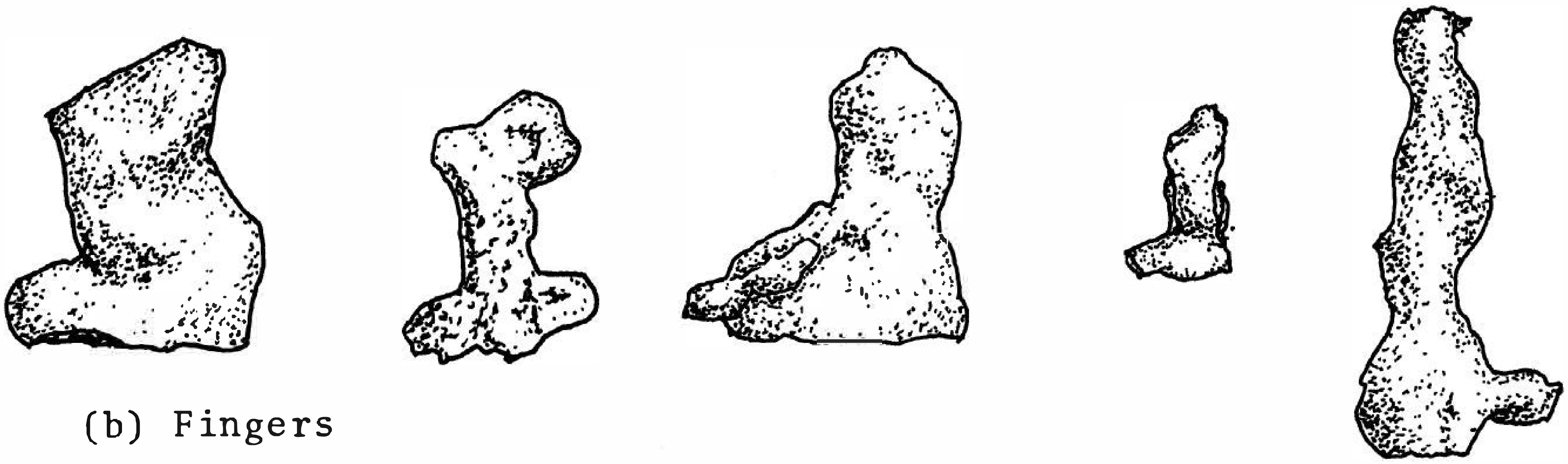


(f) Irregular

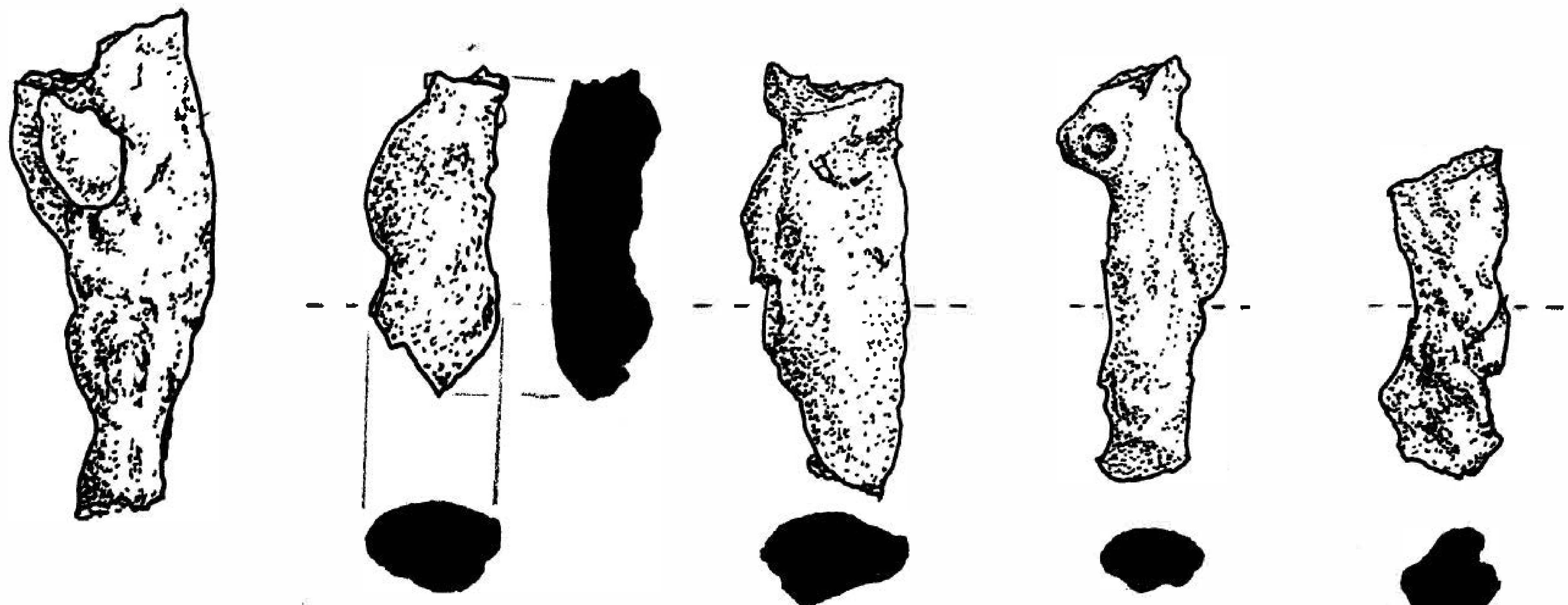
Plate 4. Slag Series. Typical Pieces. Drawn in Frontal, Posterior and Lateral Views. Natural Size (Chapter II.9.b).

(g) Cake

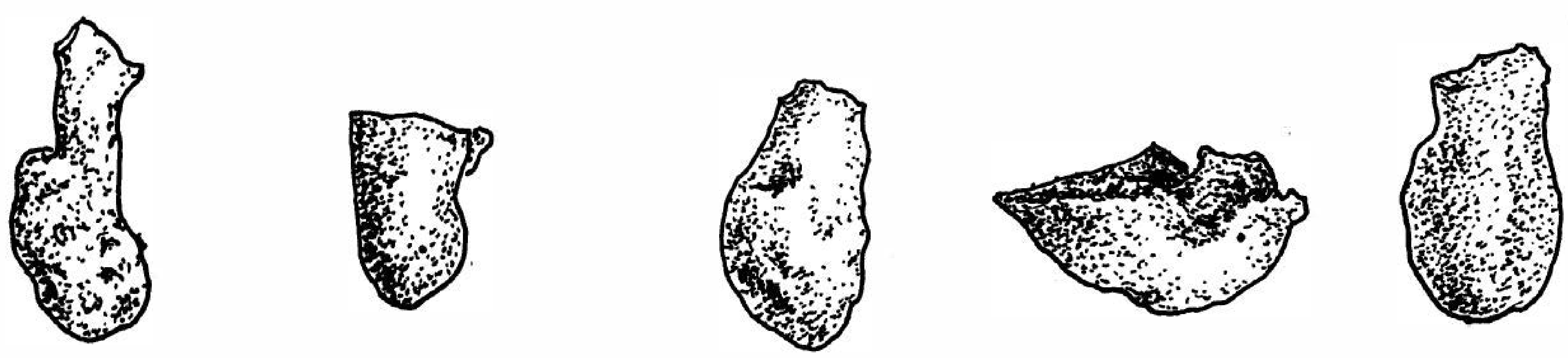
(a) "Ape Bones"



(b) Fingers



(c) Droplets



(d) Multi-fingers

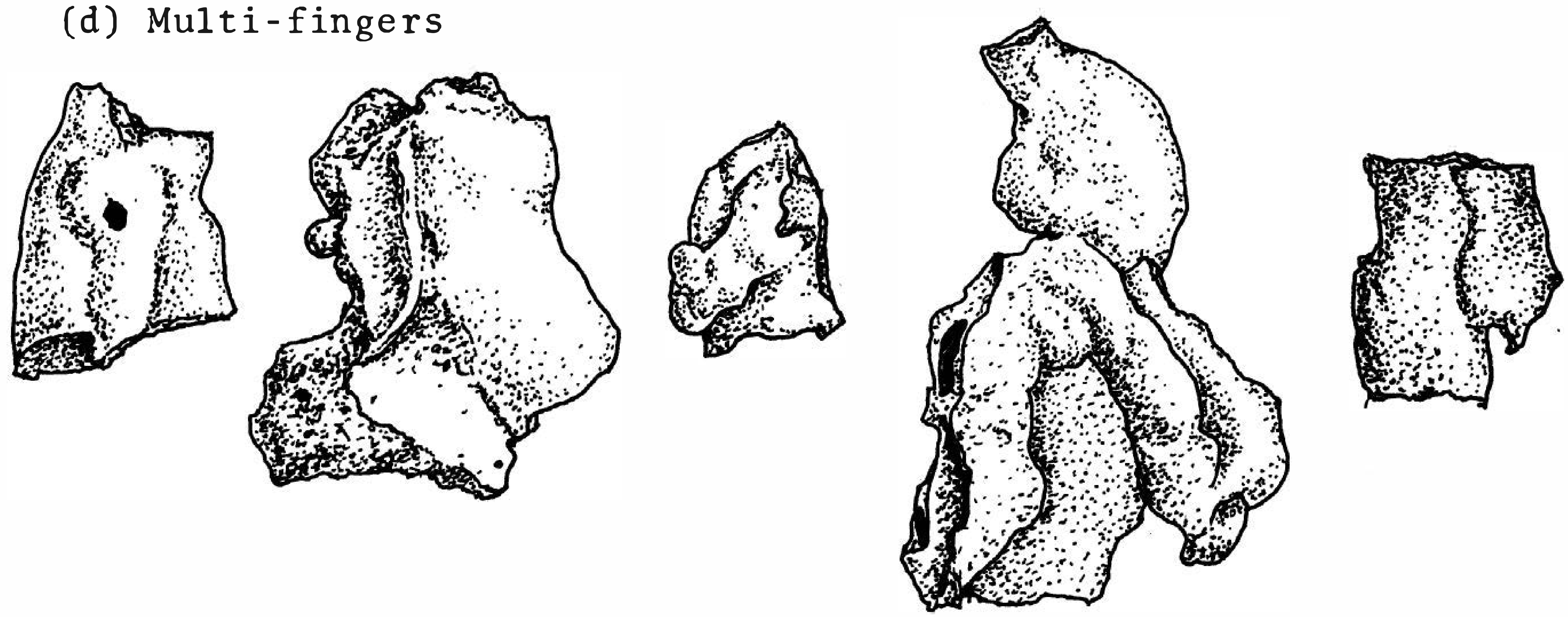


Plate 5. Slag Seriese Drawn to Illustrate Range of Variation within Typese Natural Size (Chapter II.9.b).

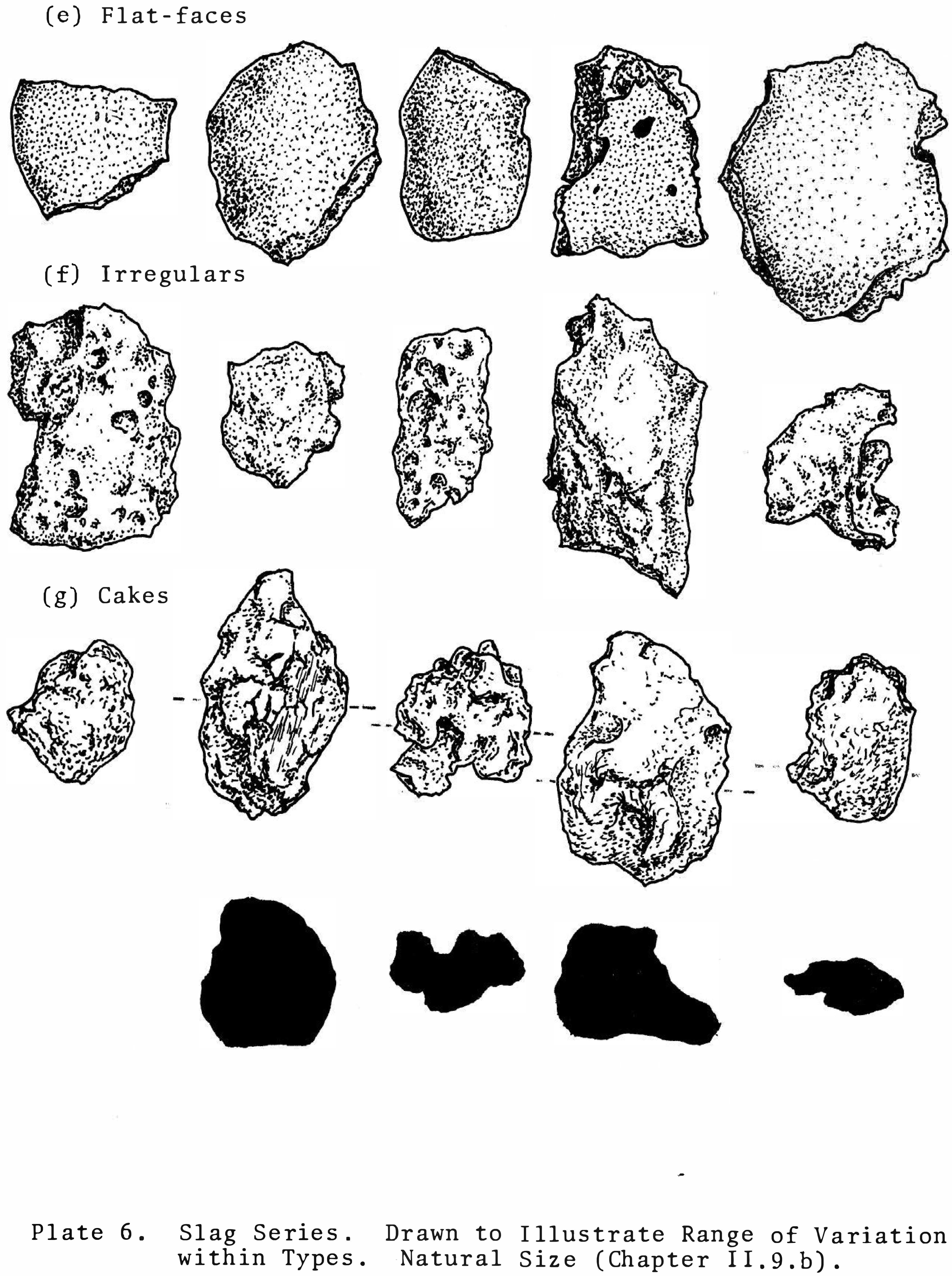


Plate 6. Slag Series. Drawn to Illustrate Range of Variation within Types. Natural Size (Chapter II.9.b).

PART III

THE EVIDENCE IN CLAY

"This image's head was of fine gold, his breast and arms of silver, his belly and his thigh of brass, his legs of iron, his feet part of iron and part of clay."

Daniel 2:32-33 (King Nebuchadnezzar's Dream).

"This was a day when shovels would have struck
Full flakes of fire out of the land like rock;
And ground cries out like iron beneath our boots."

Selected Poems of Thomas Merton, 1959.

III.13. "CRUCIBLE" AND SLAG

> About a hundred times daily it was charged through the tunnel head at the top of the stack. Each charge consisted of a bushel of half-charred wood--referred to as "brands"--18 bushels of charcoal and 640 pounds of iron ore. . . . These ingredients were dumped into the furnace in alternating layers. An air blast, entering through tuyere nozzles near the bottom of the crucible, urged on the charcoal. Molten iron ran into the hearth below, to be drawn off about four times a day. (*National Parks Mag.*, July 1968, p. 14.)

That is an account of Maramec, Missouri, pioneer smelting unit in the United States, which started with haematite first detected on the body-paint of Shawnee Indians and thus traced to the ore source (cf. IV.20). Beginning work in 1829, Maramec faded after 1870, in face of competition from modern methods such as the "hot blast" furnace. The paragraph covers about everything that concerns the student of pre-modern iron technology at any level.

This third part of this data paper is concerned primarily with the other major material evidence about iron-working that is found in abundance throughout the delta sites.

(a) Slag and Clay

Slag is the conspicuous delta site material because it is hard and survives solidly, almost immortal even on the surface. Where there is slag in quantity, there are also many pieces, highly fragmented and comparatively inconspicuous, of friable earthenware, always parts of undecorated vessels in a coarse clay and (where not wholly crushed) evidently parts of a cylindrical tube--features which will be described more exactly below. In excavation this is recovered in basically the same condition as the slag: that is, as debris, detritus. Whole vessels of this sort are unknown in the present deposit and are mostly highly fragmented. The clay body and the firing action in use render the result especially liable to disintegration, as well as the decomposition due to centuries of burial in the open.

As regards body, all this class are made of a clay which is grey to white, firing to light buff or reddish in places, with fine particles of sand, mixed sometimes with heavier materials. The same clay is widely distributed in the estuarine reaches here. Local saline mud has been tempered with local sand, as well as tiny pieces of abundant broken local earthenware pots, spicules of stone and even of Jaong slag as "grog" (III.16.g).

Broken earthenware of this kind is "all over the place" with slag, so regularly and on such a scale as to leave no doubt that this is an important correlation in the iron context. These cylindrical clay vessels cannot be confused with the familiar earthenware jars, pots, boxes and other domestic wares, which come in many shapes and sizes, but never in this form, never indeed looking anything like this.[1] What, then, are these artifacts, which occur throughout Jaong, Buah and Bongkisam? Slag is seldom found without them, and vice versa, even in individual small test trenches (as we shall see).

(b) What Were the Cylinders For?

Human activities in historic times, such as the planting of durian and other fruit trees at Buah or the rubber gardend and huts which pattern Bongkisam, substantially contributed to further disturbing and fragmenting crucible material--whereas the metallic slag was comparatively immune. There are indications that when the first modern delta inhabitants began to clear the land for cultivation, some crucible may actually have been standing, more or less unbroken and exposed, at or near the surface! H. H. Everett, the first European settler in the area, in 1909 published this description:

> An interesting find is that of crucible remains in fairly large quantities. The crucibles--apparently about 7 ins. high--were excellently made and the clay used was of superior quality; it is obvious too that the material was turned on a potter's wheel. We think it very likely that these crucibles were made in the village, and that they made use of a white siliceous clay which is still to be found at Bonkissam; this clay has been analysed by Mr. C. J. Brooks who reports that it is very similar in composition to the material of the crucibles and to that of the better kinds of pottery.
>
> A remarkable fact about these abundant crucible remains is that not one of them has been in use, as if the Santubong crucibles were made entirely for export. *The recent find of a single specimen of crucible which has been in use and which still contains a fusible slag*

does not appreciably alter the case for this crucible is made of an entirely different material, being of coarse grain whereas all the other crucibles are characterised by a special fineness of structure. The contents of the used crucible are iron slag. In the total absence of used crucibles belonging to the better class, we are unwilling to offer any suggestion respecting their use."[2]

Everett and his collaborator John Hewitt use the term "crucible" without hesitation. They do not describe or even indicate the shape. But they can only have been describing the same "cylinders" which concern us here. And their distinction between two sorts is almost certainly because they had the (unique) experience of coming upon an unused set close to the surface and did not know of the more than casual occurrence of very many more underlying, some coarse and some fine in grain, and all affected by firing. It may well be that the 1909 text reports a potter's workshop. Alas, we do not even know *where* this was in the Santubong area, now. Nor have two decades of search and research in the area produced one "crucible" or other dylindrical vessel as long as "about 7 ins. high." The longest cylinder excavated since 1947 is less than 6" (= 150 mm); but as every single one of hundreds has been broken, nearly always clearly at *both* ends, this is not surprising--the original as made is likely to have been over 6".[3]

Despite these difficulties, much merit must be attached to Everett's pioneer observations at Santubong. It is a disaster that nothing from his period survived the Japanese occupation of World War II in the Museum; and the same material is no longer recoverable today. Under these circumstances, however, another set of investigators fifty years later can only examine the delta activity to hand, from underfoot. And here we hit a serious obstacle at the start. For there is, so far as we know, *no* good archaeological information on this particular subject from anywhere else in Southeast Asia; there has been virtually *no* discussion of the early iron technology in this part of the world. So, without precedent or background from our seniors, it is all the more necessary to avoid making any assumption which could prejudice the understanding of this subject, far from easy at the best of times.

Thus it is that the most difficult decision faced by the writers has been how to address the cylinders, rings and lesser fragments of refractory whiteish to buffy clay found throughout Jaong, Buah and Bongkisam. While it would be easy enough to follow Everett at once, conventional wisdom yet suggests that when one finds such artifacts of refractory clays in iron-working sites, they are reasonably to be regarded as tuyèresŋ defined by Webster's Collegiate Dictionary (1957) as:

> an opening through which the blast of air enters a blast furnaceŋ cupola forge or the likeŋ to facilitate combustion.

A tuyère is in effect a nozzleŋ mediating between the cool-zone of an air-pressuring bellows and the harsh heat at the point of oxidization over the ore and/or metal. Such an object is hereafter called a *nozzle* in this paperŋ whenever this is clear and sufficient. It matters greatlyŋ for if these rings of clay and the more numerous broken pieces of clay in the ground are actually and exclusively damaged nozzles cast aside in the course of smeltingŋ then we could scarcely invoke a crucible process or visions of "wootz" steel cakes or any other more advanced technology upon the mudded margins of Santubong Mountain. Andŋ as we have seenŋ in some ways the smelting method in use was simple (II.10).

This indecision at the crossroads, augmented by the absence of precedent and total lack of published material for comparisonŋ underlines the stark fact that the delta material in the iron rich sectors taken collectively is a powerfulŋ mysterious mixŋ an unlikely compound of sherds of high-fired Chinese stonewaresŋ tiny colored glass beadsŋ iron slagsŋ earthenware pots and clay cylinders. This wonderfully mixed bag lies jumbled together without the saving definition of even one stone-walled hearth or masonry chimney that could be traced out to the measureŋ shape and order of a conventional furnace type bristling with a proven name.

But the absence of well-defined walled furnaces or kilns need not at all imply the absence of nozzles on the ducts or pipes bringing essential air to play on the fire processes. Such tuyère nozzles in clay have been described in *historical* times for Borneo both in native smelting and in the subsequent forging of the resultant iron. Moreoverŋ they have been described alongside and even in simultaneous use with cruciblesŋ both lots made of clayn The most important of these dual-use descriptions was published three years after Everett's by another skillful amateur observer of Sarawak lifeŋ Charles Hose; as his important account underlies the present dilemma even in this centuryŋ it will be quoted here in anticipation of our main treatment of the Borneo ethnological data.n[4] In the following quotation which refers to the interior Kayan and Kenyah peoples of the Baram River in northern Sarawakŋ four passages are italicized; the first and fourth *italics* refer to crucibleŋ the second and third apparently to tuyère nozzlesŋ all of clayŋ although the account is far from clear in detail and also contains no measurements or other detailsn

Even at the present day the native ore is still smelted in the far interior, and swords made from it by the Kenyahs are still valued above all others.

Smelting and forging demand a specialised skill which is attained by relatively few. But in each Kayan village are to be found two or three or more skilled smiths, who work up for a small fee the metal brought them by their friends, the finishing touches being generally given by the owner of the implement according to his own fancy.

> *The smelting is performed by mixing the ore with charcoal in a clay crucible, which is embedded in a pile of charcoal.* The charcoal being ignited is blown to a white heat by the aid of the four piston bellows. Each of the bellows consists of a wooden cylinder (generally made from the stem of a wild sage palm) about four feet in length and six inches in diameter, fixed vertically in a framework carrying a platform, on which two men sit to work the pistons. *The lower end of each cylinder is embedded in clay,* and onto it near its lower end is inserted a tube of bamboo, which, lying horizontally on the ground, converges upon and joins with a similar tube of a second cylinder. The common tube formed by this junction in turn converges with the tube common to *the other pair of cylinders, and with it opens by a clay junction into a final common tube of clay, which leads to the base of the fire.* The upper extremity of each of the piston rods is attached by a cord to one end of a stout pliable stick, which is firmly fixed at its other end in a horizontal position, the cord being of such a length that the piston head is supported by it near the upper end of the cylinder. Two men squat upon the platform and each works one pair of the cylinders, grasping a piston-rod in each hand, thrusting them down alternately, and allowing the elas-tic reaction of the supporting rods above to draw them up again. *The crucible, having been brought to white heat in the furnace, is allowed to cool,* when a mass of metallic iron or steel is found within it. (Hose 194)[5]

All of the above account would be applicable in the prehis-toric delta context. No elaborate walling or kilning is implied. Assuming for a moment something of the kind was developed in the Sarawak River in centuries past, this would leave behind two sorts of clay debris. But in the present state of decomposition no equivalent differences in shapes have been detected at any delta site.

If something *other* than the prehistoric cylinders could here be reconstructed, it would be easier to meet the clear need for some sort of nozzles on air conduits exposed to heat. But in so far as such nozzles in Borneo were consistent with the ordinary tuyères of the literature, they cannot clearly be separated from what we have decided to regard primarily as crucibles. The reasons for this decision must be briefly stated; then two alternative solutions of the apparent dilemma may be considered.

(c) Crucible and Tuyère (Nozzle) Compared

Four main considerations effect this issue--(i) size and shape; (ii) breakage, and other evidence of use; (iii) quantity and distribution; and finally inferential evidence from ethnology, etc. (as already indicated, with more to follow).

(i) Size and Shape

Nozzles with minimum diameters of ½" to 1" have been found in European iron sites of the sixth to tenth centuries A.D. and these are illustrated by R. F. Tylecote in his invaluable "Metallurgy in Archaeology" (London, 1962: fig. 47 at p. 200). The largest are about 5" long, most smaller. They come in several shapes, but *all* have three features in common:

- --a marked taper, both external and internal, to a conspicuously smaller end;
- --an exit hole narrow by comparison with the entrance (larger) end;
- --this exit hole does not exceed 3/4" in diameter (under 20 millimeters).

The delta cylinders have a slight external taper in most (not all) cases, but this is mainly external. There is no pronounced internal taper, and no case of a hole at either end with a diameter under 1" (*ca.* 25 mm).[6] Tylecote has emphasized (201) that ½" is a necessary end diameter on the basis of experiments. The point is, of course, that a smallish tapered nozzle propels the air with more force. Continuous wide cylinders of some 30 mm. diameter, common in the delta, would have required high pressure to have been effective as an air conduit; but that would not have been out of the question with the advanced type of bellows in area use.

On the other hand, western parallels can be extremely misleading. There are equally no crucibles from the west which resemble the Sarawak ones (cf. Coghlan: 88).

On this R. J. Forbes has well said:

> These tuyères have often been found in ancient smelting furnaces or on smelting sites, and though they have *often been disregarded* they form certain evidence that blast air has been used. The ethnological evidence and theories on the evolution of the bellows have been *neglected* by the archaeologists, but we must necessarily draw on them to supplement the very meagre archaeological data (114; our italics).

Apart from Hose's crucible of unspecified shape, we have the very unclear early account of Schwaner (in Dutch) written in 1845 for interior Kalimantan, which appears to describe clay nozzles attached to 29" long bamboo pipes; these nozzles were apparently "long and tapered from 2.5" down to the size of a thumb" (i.e., less than ½"; see "Borneo," Amsterdam, 1853, p. 109, translated and annotated later in Appendix A). This account is important as the only fairly definite record of any sort of clay nozzles in Borneo large enough to be considered relevant to the delta cylinders, from which however the differences are evidently major.[7]

One other point of size and shape should be mentioned. With nozzle-type objects, the incentive would be to thicken the wall as much as possible--to avoid heat eroding it and insure safe air passage. With crucible-type vessels, the incentive is reversed: the thinner the wall the better the outside heat can get at the contents which is the main object of the operation--provided of course that the wall does not collapse. As statistics below will show, the delta premium is on thinner walls--and as time went on, they were thinned down too. *In most tuyères the internal diameter is regularly under half the external; this is never so in delta cylinders.*

(ii) <u>Breakage and Other Evidence of Use</u>

Hundreds of thousands of broken pieces of these clay cylinders occur in the delta deposits, intimately with the iron slag. Allowing for all kinds of secondary breakage, the relatively small number of whole "rings," complete cross-sections of cylinders up to 135 mm. long, are themselves always broken, and nearly always at both ends. None show any distinctive nozzled or enclosed end, as already noted.

Up to a point, that is evidence in favor of use as pipes or conduits; for most crucibles have one end enclosed, too. But why should they be *broken* in this way? Is it necessary to *break* nozzles at all? A tuyère nozzle becomes unworkable once its internal diameter sags, clogs, melts or in some way obstructs the passage of air. Useless nozzles would be thrown away more or less intact rather than broken; or patched up with fresh clay. At least one would have been recovered in that condition by now. Crucibles, on the other hand, *must* be broken in order to extract the hardened metal. Recognizing, of course, that nozzles might be casually broken in the destruction of non-functioning kilns or hearths, the characteristic occurrence of many many thousands of broken pieces of cylinder creates a further distinct--though not final--presumption in favor of crucible or related use.

This presumption is neither strengthened or weakened by other indications on and about the cylinder surface. Charring, burning, metallic accretion, are common on large cylindrical pieces, focused at one end. This could equally be explained by charring of a nozzle at the fire face or by the application of heat to one end of a crucible--as is clearly the case in Hose's Kayan crucible usage cited above, and was established for southern India by Heath in 1839 where crucibles were arranged in an arch, bottoms facing in to the furnace.[8] Heath also describes bellows-operated "bamboo nozzles" leading into a clay pipe carrying the air through the furnace at ground level. None of these vessels are exactly described, however.[9]

The much rarer cases where the *inside* surface of the delta cylinders carries any clear evidence seem, however, unequivocal. In a small but significant number of cases from all three sites, the inner chamber contains appreciable metallic accretions, in positions where it would be stretching common sense (the archaeologist's court of final appeal) to deduce that the stuff had somehow been drawn or run in from any sort of nozzle-conduit situation. For one important case, Bongkisam II, 12-18" (1955) the whole interior is plugged with some sort of "iron" for a distance of 2", probably due to some kind of mistake in recovery or firing where normally the contained ferrous cylinder would have been removed. However, such cases *are* markedly rare.

(iii) Quantity and Distribution

In a single Jaong trench of 1966, Y/1, 5' x 5', there were 2,800 pieces of cylinder (= 112 pieces per surface sq. ft. on the measure earlier established for slag; II.7.c).

This sort of figure is commonplace for the delta. Cylinder is spread over hundreds of thousands of square feet, in effect over all the 25 acres of main slag deposit and most of a similar area of lesser slag (and cylinder). They occur, too, at all depths and in all slag situations.

(d) Crucible First; Plus Other Uses Secondary

The evidence is ambiguous but seems to give a slight edge in favor of crucible use, even though the exact method of use is far from resolved. The very close association of cylinders with slag suggests that smelting and crucible use was closely identified, either as part of one process (in smelting of the manner described by Hose for the Kayans in this century) or as an essentially associated process in which the smelted product, cleared of slag, is at once refined in heated crucibles, as with the *wootz* iron and its conversion to steel, highly developed early on in India (as illustrated in VI.34.a). We can better resolve such uncertainties after examining the cylinders more closely in the delta setting as a whole, and this will be the concern of the following chapters, leading hopefully to some more specific conclusions (at III.19).

Meanwhile it is needful to insist that *because these clay cylinders apparently were used as crucibles, this does not necessarily preclude any of them from being used as tuyère nozzles too.* On the contrary, it is a bit difficult--though not *very* difficult--to believe that no such nozzles or conduits were used to carry air far into the fire in these prehistoric operations. The long cylindrical crucible in itself involves a concept so technically "advanced" (in advance of most in that field at that time in Europe!) and the clay with its know-how is so palpably present in the delta, that it would seem "natural" to use it in *both* ways, nozzle and crucible. But it is seldom safe to apply such outside standards of rationality to the extremely subtle processes at work with men and their materials in lands like Borneo. Moreover, the area is handsomely supplied with another natural product, bamboo, which comes in all sizes from elephant's truck to hypodermic syringe. A simple application of wet mud--the same stuff as crucible clay--over the nozzled shapes of growth could well serve in certain circumstances.[10]

Although most descriptions of smelting in Borneo since the earliest in the 1840's, mention some sort of tuyère, two early accounts by generally very reliable observers clearly indicate the *absence* of these in the ordinary sense. Both accounts refer to southwest Sarawak, the Dayak peoples living in the upper Sarawak River and adjacent hill country directly related to the delta area for ore supply, etc.--whereas the Kayans are, of course, 300 miles away with (until very recently) virtually no direct contacts between the two peoples.

Admiral Sir Henry Keppel, writing in 1846 of the Sebayau Dayaks (who have direct access by water to Santubong), describes how from a bellows of two hollow trees:

> . . . two pipes of bamboo are led through a clay-bank three inches thick, into a charcoal fire."[1]

Apparently here the clay-bank screened the nozzle of bamboo. Naval Captain Mundy, writing in 1848 for the same area, gives a very clear and full description which includes:

> . . . two larger bamboo canes, about 3 feet long, and 3 to 4 inches in diameter, for cylinders,--a small cane inserted at the bottom to act as the tweer, and a bundle of feathers as a piston--the apparatus is completed."[2]

Mundy's account (of smelting) leaves little room for doubt that in this case the tweer (tuyère) was simply the bamboo without even Keppel's clay-bank. This may well have been a southwestern system, differently developed by the Kayans and the Kenyahs and others further north and inland. But again, it is important to recognize that the dynamic *and* diverse peoples of Borneo may have used several methods as well as modified them in several directions after the initial experience.

There are also other and much less conspicuous clay objects in the deposits which have hitherto perhaps been mis-classified and which could also act very well as nozzles on a limited scale. Some of these are small and in use could easily escape observation by a field observer (see III.16. c-d).

It all comes down, in the end, to the degree of elaboration and the "scale of power" employed in the initial smelting. The simpler this was structurally--and nothing could be simpler than St. John's long pre-Hose account of Kayan smelting in the *same* area as Hose--the less the need for sizable conduits and defined nozzles; and the less the need to make these of high heat-resistance, durable. As the delta evidence favors a relatively simple smelting hearth, the emphasis in this case is not towards the sort of elaboration described by Schwaner in Kalimantan--where over the centuries, ore problems and more outside ideas may have extended an original process by the nineteenth century. It may be best to leave the final question unresolved, pending the deeper research into the early iron age which is so clearly required in Southeast Asia, where much more is now known about the stone age. There is no reason on or under Bornean earth why the delta crucibles would not have been employed in other capacities as well. It would be especially feasible to think that *used crucibles, broken off but still in excellent shape over shorter lengths,* were secondarily re-employed to fit over bamboo pipes as tuyères. Similarly, the original, longer, unbroken crucible (6-7"?) could be interchangeable as an air conduit through a furnace wall or over a hearth floor, in the way described for several Indian and other sites ethnographically.

H. H. Coghlan has said:

> Again, when tuyères of baked clay are found in association with the furnace, there is strong evidence for the use of a bellows and air-blast. It must, however, be remembered that (as in the case of some modern primitive African furnaces), a number of clay tubes spaced round the lower part of the furnace may be used to provide, or to regulate, a natural draught. *Conical tubes or tuyères point to the use of the bellows rather than do cylindrical ones. Also, cylindrical tubes which are long enough to pass through the wall and lining of European furnaces do not, as yet, appear to have been recorded.* (88)

But in Borneo the advent of an iron technology in (though not directly *from*) the T'ang dynasty excited a tremendous socio-economic unheaval. Standing at the corner of a great triangle with its other two angles somewhere near Gujerat in west India and Peking in north China, the southwest end of Sarawak became for a time a meeting point of new, dynamic methods and ideas, impacting on a people ready to learn and resilient to innovate. Nothing can be so absurd as to visualize the "primitive Dayaks" as accepting, dull serfs. Experiment and dynamic effort were pre-essentials for even the simplest good life in this environment; and continues so to this day.[13]

And lest the foregoing has seemed to lean in any particular direction, this introduction to crucible and related clay in the delta can suitably be concluded from another source referring to China before 250 B.C.:

> The iron industry of Chou China owed its development to the bronze technology which had reached its height in the Shang period. *The fundamental technique was the crucible process which was made possibly partly by the discovery of good refractory clay in the ceramic industry.* (Cheng, 1963: 246)[14]

III.14. CRUCIBLE QUANTITIES AND ASSOCIATIONS

In the delta, crucible (as defined in the previous chapter) in the ground is frequently difficult to distinguish from the slag itself, especially in the "cakes" which form a small but conspicuous part of some concentrations (II.9.e). Quantitative crucible estimates, either by weight or count, are inevitably of surviving residues, far more perishable than the slag. They give an absolutely minimal picture of crucible content in any site or at any depth. On the whole, the deeper the layer the larger and stronger the pieces that survive the pressure--especially where there is dense and heavy slag. We will now summarize information on this aspect, in so far as it is helpful to the understanding of the crucible role and iron-working as a whole.

(a) Crucible Residues

Although delta crucible has been fire-heated into a fairly durable form, it crumbles rather readily on exposure and is brittle under pressure. Like earthenware pots, it is usually much fragmented under the pressures of soil, slag, time depth and disturbance. Not only is there no one perfect crucible from the excavations; far the greater part of it is in small pieces which cannot readily be classified as crucible at all except through experience in handling. A very small proportion of pieces are recovered as parts which show a cross-section of the original form--that is, a complete round of intact wall which may be from a few millimeters high (length) to over 100 mm. These give direct information on crucible form, and hereafter are termed "rings." Rings are included in the figures for other sherds ("pieces") in our treatment; except where otherwise stated the larger rings are then considered separately for shape, size, cubic capacity, etc., in the following chapter (III.15).

The same broad distributional considerations apply to crucible as to slag. It is "all over the place" in the main sites, at all levels. It often shows marked irregularity in both vertical and horizontal distribution, marked variation from one sector to another inside any one site. Yet it is as persistently similar and continuous in basic typology as the slag itself. Nowhere has it been identified without slag; seldom has slag been found without crucible. The slag is derived largely from smelting in presumably pre-crucible activities in the open-hearth, bowl-furnace smelting which we have proposed as the essential base-unit for the delta operations (II.10). Refining the wrought iron into steel by smelting in a crucible produces a lesser slag of its own, but it has not proved possible to isolate such slag under delta conditions. The presence of crucible almost everywhere with the massive smelt-slag however suggests that the two operations closely integrated--and perhaps went on side by side; even (and logically) in combined units simultaneouslyt

Separating and enumerating delta crucible is even more difficult and tedious than doing this for slag, as earlier described. The local crucible distribution pattern runs in parallel with the slag. There is no need to document every aspect again statistically. We will take only the main points.

(b) The Amount of Crucible

There are parts of the delta sites where slag and crucible are overwhelmingly dominant; even so in maximum concentrations, stonewares and earthenwares in particular are *never wholly absent*. For example, Jaong trench Y/1, 5' x 5', produced 1,669 lbs. of slag and 95 lbst of crucible. In terms of sherds (pieces) this Y/1 gave:

--*ca.* 2,800 *crucible* pieces
-- 106 stoneware sherds (Chinese)
-- 172 earthenware sherds ("local")

Two trenches of the same season and size, Y/2 and Y/3, further out from the main slag concentration by the Jaong creek, and therefore less rich in crucible, gave:

--*ca.* 420 *crucible* pieces
-- 73 stoneware sherds
-- 96 earthenware sherds

A different pattern comes from the slag-rich trenches excavated at Bongkisam in 1955 (II, JJ, etc.), which gave:

-- 3,107 *crucible* pieces
--49,393 stoneware sherds
--67,668 earthenware sherds

This sector at Bongkisam, near the river mouth, was more heavily a trade and contact point than Buah and Jaong upriver, though by no means exclusively sot

At Buah, crucible actually outnumbered slag pieces in some trenches of 1954, such as D/2, though this is rare:

Buah: Slag and Crucible Compared (by pieces)

Depth (inches)	Crucible	Slag
0 - 24	24	0
24+	130	14
ALL	154	14

Although the Buah D/2 situation is unusual, it is important. For here and at a few other points we find crucible --clearly *used* (as in *all* cases during the excavation) crucible--out of all proportion to slag. This probably indicates that although the two main activities normally overlap with smelting in the ascendency over refining as regards bulk in the deposit, nevertheless there are places where this situation is reversed and refining clearly predominates. The two did not have to be in any fixed relationship at all times. Either operation could be and no doubt was carried out separately from the other as required.

The number of pieces is a very rough guide only, especially where comparison is with something so different in quality as metal slag. But it is difficult to find *any* really satisfactory index for such comparison which is at the same time practicable in terms of delta-type excavation field-work.

(c) <u>A Piece/Weight Factor</u>

As with slag, in practice one has to fall back on weight. This is the least susceptible to masking effects such as the way clay vessels may be much more fragmented in one case than another, so that on the one hand 50 pieces may represent one crucible, at another 2 or 3.

Using, of necessity, the weight method, it was found that subject to the usual wide variations, a rough yardstick was:

--30 pieces of dry delta crucible average 1 lb. weight;
--50-100 pieces of slag average 1 lb. weight (see II.9.c).

Obviously, there is a special potential for variation here--the larger pieces of recovered crucible reach 1 lb. (and a few slags reach several lbs.). Put this way, the

Buah D/2 ratio of 11:1 in favor of crucible over slag in not much affected and certainly remains as one of the rare positions in favor of the former.

There is also the distinct tendency for crucible pieces to be larger and heavier *downward* in a deposit. 1,417 of the pieces of Bongkisam crucible in trench II were taken as a sample for analysis from this point of view--the balance of 59 pieces originally excavated disintegrated after exposure and could not be separately identified. The following table illustrates the common, though not at all invariable, trend:

Crucible Dry Weight/Number Relationship
At Bongkisam, II Only (1955)

Depth (inches)	Weight lb.	ozt	Count (pieces)	Average number of pieces per lb.	Number of "Rings"*
0 - 6	1	14	102	51	2
6 - 12	15	2	508	33	23
12 - 18	21	10	547	25	21
18+	11	6	260	24	10
Total	50 lbs.		1,417	29	56

*Rings as defined previously in (a).

With the usual exceptions, crucible pieces average smaller at the top and mainly survive as larger pieces *lower down in the deposit,* under pressure. This of course affects all piece-count comparisons by depth, and puts a rather better value on comparison by weight. [More depth factors will be examined at (e) below.]

(d) Crucible:Slag Ratios

A positive ratio in favor of crucible over slag is very rare in the delta as illustrated with Buah D/2 above. The much more usual pattern is illustrated below, with examples from trenches already discussed under the slag chapters, which can be checked back for comparison.

Some Crucible:Slag Comparisons

Site	Trench	Ratio of Crucible:Slag	Calculated by
Buah	W/1	1:18	weight (to oz.)
	W/2	1:51	weight (to oz.; cf. II.8.e)
Jaong	BL/1-3	1:54	weight (remote trench)
	C/1	1:7	weight (cf. II.8.c, first table)
	D/1-9	1:11	weight (II.8.c, second table)
	G/1-3	1:40	weight (II.8.c, third table)
	H/1	1:15	sample small (cf. as above)
	M/1	1:24	weight (to oz.)
	M/2	1:13	weight (to oz.; *see below at e*)
	X/3	1:45	weight (to oz.; cf. II.8.d)
	Y/1	1:17	weight (to oz.)

The general pattern is of slag outweighing crucible by between 7:1 and 54:1 with an approximate "norm" around 20:1. This still amounts to quite an enormous amount of crucible!

These figures should be of value in future analyses of *other* iron sites in this part of the world, where application of a similar standard could provide one of several comparative features fairly easy to measure and likely to illuminate the general prehistoric set-up, albeit superficially.

(e) <u>Vertical Stratification of Cruciblet Inch by Inch</u>

At both Buah and Jaong trenches have been excavated in 1" layers with meticulous recovery of all materials, as described for the slag (II.8.d). Since the general point of variation has already been made, a simple example will suffice in this instance.

Jaong M/2 has been selected here because it has a fairly high crucible:slag ratio, 1:13. The other trenches with correspondingly exact data are over 1:50, which means that on a 1" layer system the figures are often very low, even below 1 oz. per inch. With M/2 one gets a very fair idea of how this crucible runs vertically. It is present in all but eight of the 1" layers--the top three (which contained a little slag)--at 19-20", 25-26", and 30-31" and then down at 42-44" (when slag was quite heavy, at 10 lbs. 2 oz.). One of the heaviest crucible concentrations, 16 oz., is right down near bedrock, at 46-47"; and the heaviest, 22 oz., under the surface soil at only 8-9". In this sense, crucible covers every level of smelted slag except the immediate sub-surface (where it is less likely to survive secondary disturbance and weathering than the slag itself):

Jaong, M/2, Crucible Weight in One-Inch Layers

Depth (inches)	Crucible lb.	oz.	Depth (inches)	Crucible lb.	oz.
0 - 1	-	-	24 - 25	0	1
1 - 2	-	-	25 - 26	-	-
2 - 3	-	-	26 - 27	0	1
3 - 4	0	4	27 - 28	0	1
4 - 5	0	4	28 - 29	0	2
5 - 6	0	4	29 - 30	0	4
6 - 7	0	8	30 - 31	-	-
7 - 8	0	8	31 - 32	0	2
8 - 9	1	6	32 - 33	0	1
9 - 10	0	6	33 - 34	0	4
10 - 11	0	2	34 - 35	0	6
11 - 12	0	4	35 - 36	0	2
12 - 13	0	1	36 - 37	0	3
13 - 14	0	1	37 - 38	0	2
14 - 15	0	2	38 - 39	0	6
15 - 16	0	4	39 - 40	0	5
16 - 17	0	4	40 - 41	0	2
17 - 18	0	1	41 - 42	0	1
18 - 19	0	5	42 - 43	-	-
19 - 20	-	-	43 - 44	-	-
20 - 21	0	2	44 - 45	0	2
21 - 22	0	6	45 - 46	0	2
22 - 23	0	6	46 - 47	1	0
23 - 24	0	2	47 - 48	0	1

Similar information can be reduced from 1" to 6" layers for a Buah comparison, including the slag figures in this case.

Buah, W/1, Six-Inch Layers, Crucible with Slag

Depth (inches)	Iron Slag lb.	oz.	Crucible lb.	oz.
0 - 6	-	-	-	-
6 - 12	2	1	0	1
12 - 18	5	9	0	1
18 - 24	9	13	0	1
24 - 30	9	13	0	2
30 - 36	10	15	0	3
36 - 42	12	3	0	11
42 - 48	36	5	1	10
48 - 54	29	10	2	6
54 - 60	23	0	2	5
60 - 66	19	0	0	11
66 - 72	15	8	0	12
72 - 78	13	4	1	8
78 - 84	5	8	0	0
Total	192	9	10	7

(f) Wider Vertical Patterns

A broader idea of vertical distribution for crucible comes from a series of Jaong trenches all already tabulated in connection with slag and thus available for direct comparison, in this data paper. As we have adequately discussed the finer points of layering for slag and again illustrated this for Jaong M/2 crucible just now, the following figures are rendered into 12" layers only, for brevity's sake. In the first table, those trenches where the figure is for percentage of *pieces* (sherds) are italicized (i.e., E, F, N); the rest are by *weight* in the ordinary way. All cases with zero crucible below 30" are due to bedrock or sterile sand at or closely under that depth. This sort of analysis repeated for Buah, in relation to the generally deeper deposit here, gives a similar picture. Looking at these (and other) results as a whole, it appears that crucible is *more* variable even than slag in vertical zonation; it is not so liable to concentrate around a median line. There are rather more marked fluctuations in depth for slag, with pattern extremes illustrated by F/Jaong with 75% in top 12" (but actually three-quarters of this was *under* 6" and bedrock came in at

24") as against W/1 Buah with 73% under 48" (over half of this being between 48-60", but continuing strongly right down to 72-84").

Jaong: Crucible by Depth, as Percentage Total of Each Trench Layer

Trench	Depth (inches)				Total
	0 - 12	12 - 24	24 - 26	36+	
C/1	30	67	3	0	100
D/1-9	71	23	6	0	100
E/1-3	55	37	8	0	100
F/1x1-12	75	25	0	0	100
M/1-2	48	17	15	20	100
N/1-4	18	49	33	0	100
X/3	6	55	37	2	100
Y/1	41	39	19	1	100

Buah: Crucible by Depth, as Percentage of Each Trench Layer

Trench	Depth (inches)			Total
	0 - 24	24 - 48	48+	
DE/2-13	32	35	33	100
W/1	2	25	73	100
W/2	12	40	48	100

(g) Crucible cf. Slag by Depth

There is no consistent relationship between crucible and slag in quantity in the delta sites. It is rare to find one without the other. It is unusual for crucible to occur *relatively* more--or, to be exact, more in recoverable, identifiable piece form--in ratio to slag towards the higher levels, as it does in Jaong G/1-3 (1:14 cf. 1:40 for whole) and again at M/2, where it is 1:6 for both 0-6" and 6-12", then drops to 1:14 and 1:36. More usually, crucible is relatively more present in the median layers, as in Jaong X/1, 12-24" (1:25 cf. 1:45 for the whole), or at Buah W/1 (1:12 cf. 1:18). But the higher ratio can come in the lower levels too, as at Jaong C/1, which is a very high crucible trench in any case. D/1-9 at Jaong has high crucible ratios at 6-12" and then *again* at 24-36", the same is the case for M/1 and Y/1, there, while Buah W/2 shows a somewhat similar pattern.

The result is to confirm the persistent but not consistent, continuous but highly irregular, relationship between the two main evidences of iron working through the delta.

(h) Distribution of "Rings" (Only)

Crucible rings (pieces which include a whole circle of the original circumference) are probably better indications that the crucible was actually used on that spot than lesser fragments, which could have been re-used, as scrap--to help make a hearth base for instance. Rings occur in all the working sites with a distribution broadly in parallel to the less distinct sherds, but mainly in the slag concentration sectors. They represent somewhere between 1% to 6% of all crucible pieces under these conditions. Four percent is as near an average as we can usefully get.

A sample of the larger rings are considered in detail (and with depth data) in the next chapter, where they can be seen as occurring, like the lesser sherds, at all levels, including down to 78" at Buah and 48" elsewhere. A crude tabulation of rings (all sizes) from all these sites may serve to give a general idea here, remembering that the relative scarcity of complete rings deeper can often be one result of more pressure, later disturbance and fragmentation deeper down (especially at Bongkisam)--rather than reflecting a "real" prehistoric difference. Everything goes to show that these delta iron-workers started with a crucible-like process, and ended with it, without any major change throughout (cf. IIh.15 for details).

Crucible Rings (Only). Percentages for Three Sites Compared by Depth

Depth (inches)	Jaong	Bongkisam	Buah
0 - 12	26	39	43
12 - 24	39	57	15
24 - 36	21	3	12
36+	4	1	40
	100	100	100

(i) <u>Overall Total for Crucible, etc.</u>

The reader shall be spared a replay of the method used to calculate the bulk of iron slag in the deltat But if our suggested "average" ratio of 1:20 for crucible to slag by weight is acceptable, then the known delta sites calculated on the same basis as that already detailed for slag would be:

--*ca. 2,000,000 lbs. of crucible for all sites* (as listed at III.8.j)t

A very few of the largest crucible rings recovered by excavation exceed 1 lb. in weight, but these have been fired and are impregnated with other materials. A typical delta crucible before use could not have weighed 1 lb.t[1] But taking a one pound figure, to be very conservative, the number of crucibles used on the above basis is:

--2,000,000 crucibles used on the sites.

It would probably be better than safe, however, to double this figure to four million. Taking a median three million and allowing that this was the minimal usage over only three centuries, we may indulge in a final speculation of substancet Say that crucible was in use during 250 working days of each year (which seems reasonable) and that the crucible process was employed once on each working position eacht day (which seems minimal). That would work out thus:

$$3{,}000{,}000 \div 300 = 10{,}000$$
$$10{,}000 \div 250 = 40$$

This in fact would mean that on any one working day no more than 40 crucibles would be in use. We believe that at least 5 crucibles were used at any one position at a time, so this would leave only *4 positions on any one day*. If, however, more crucibles were used in one day--and the process is only one-time, one-way--and more together at one time, we quite easily can have only one main position per diem.t[2]

This is a generous use of some very uncertain statistics. But it seems to show that the bulk results are consistent with prehistoric ground realities. Of course, it may not have happened exactly like that at all, e.g., it is likely that iron-working was in part seasonal in the delta, as well as highly susceptible to religious taboos and time limitations. But it *could* have happened so. What finally counts is the cumulatively massive end result, the metallic message spelled out across the years and spread throughout the area.

III.15. CRUCIBLE SHAPES AND SIZES

(a) Cylindrical Data

All delta crucibles which can be recognized as such are cylindrical. Prehistoric crucibles of cylindrical shape appear to have evolved largely, indeed almost entirely, in Asia, though there are very interesting parallels in East Africa too (possible of Asian origin). For instance, Tylecote's illustration of 22 prehistoric British crucibles recovered over the past 2,000 years, shows a wide range of iron age forms, none of which resemble anything from the Sarawak River delta (132). His "typology of clay crucibles" (Table 53 at p. 135), with 15 categories, includes "cylindrical flat bottom," a tiny round bowl, from a prehistoric site in Ireland. When we come east into India, this lack of parallelism gradually disappears. To cite one example in anticipation of a fuller comparative discussion (at VI.34), from Ananda Coomaraswamy writing of a historical steel-making process in cylindrical crucibles after initial smelting:

> The hearth is defined by a low clay wall, rising about six inches above the ground. The steel is made in clay crucibles, each but eight inches long, two inches in diameter, and a quarter of an inch in thickness. (1950: 192)[1]

Sarawak River delta crucible, as recovered, is shorter than eight inches, but always broken. The two other measurements are not so affected by breakage. Two inches (51 mm) is frequently the delta diameter, especially at Jaong. Quarter of an inch is below the delta average, though frequently they are that thin. But then, it is a long way from Ceylon to Santubong.

There is, unfortunately, almost no measured information from our area with which the delta data here offered can be compared. Yet this is a matter of the greatest interest in any fuller future reconstruction of the more advanced aspects in the production of steel, which revolutionized life all through the islands. The crucible is the crux of a distinctive skill which must have been very much more widespread throughout Southeast Asia and of which it is the easily identified indicator--as iron slag is indicator of a more generalized smelting activity. No hint of apology is needed, therefore, for placing the crucible form data fully on record at this stage, even if final decision on usage is deferred.

In all cases, at all sites, these are incomplete sections. In no case has a perfect whole crucible been found in situ over the past two decades of patient search. This means that the lengths given in the following tables are invariably shorter than the original vessel. In any set of measurements the longest rings will probably be nearest to the original average, and the short ones may be only small cross-sections of the original. External and internal diameters and wall thickness measurements are not subject to this disadvantage, except in so far as their position on, along, the cylinder, and thus the possible effect of tapering or irregularity: this factor will be demonstrated statistically--it is not large since the degree of taper down the cylinder is generally small. The thickness of each crucible is of course obtained by subtracting internal from external diameter, and dividing by two [cf. (e) below].

(b) Bongkisam Type Sample for Size

The longest series of crucible section "rings" measurable within the above limitations is that from the big trench II, excavated at Bongkisam in 1955. As will be seen, thist crucible as usual comes from all depths in that (relatively shallow) deposit:

Bongkisam II: 53 Measured Crucible Ring Sizes
(measurements in millimeters)

Depth (inches)	Across Larger End		Across Smaller End		Greatest Length
	External Diameter	Internal Diameter	External Diameter	Internal Diameter	
18 - 24	58	34	45	29	89
12 - 18	58	34	54	35	80
12 - 18	55	30	51	32	75
6 - 12	53	32	43	29	133
42 - 48	52	35	40	23	77
12 - 18	52	33	43	28	114
12 - 18	52	30	40	25	56
12 - 18	49	30	42	29	101
6 - 12	49	30	45	31	68
18 - 24	49	30	43	29	73
18 - 24	49	31	40	30	65
6 - 12	47	30	40	30	64
12 - 18	46	29	33	30	127
12 - 18	46	35	35	32	62
12 - 18	46	27	43	26	52

Depth (inches)	Across Larger End External Diameter	Across Larger End Internal Diameter	Across Smaller End External Diameter	Across Smaller End Internal Diameter	Greatest Length
6 - 12	45	32	44	29	75
12 - 18	45	29	41	27	72
18 - 24	45	29	45	26	69
18 - 24	44	32	42	29	80
6 - 12	44	30	29	26	85
6 - 12	44	24	36	26	90
18 - 24	44	28	39	27	89
12 - 18	44	27	43	28	75
12 - 18	44	29	40	26	59
12 - 18	44	30	43	35	55
18 - 24*	43	31	32	30	81
12 - 24	43	29	32	28	73
6 - 12	43	33	32	26	61
18 - 24	42	24	36	22	59
6 - 12	41	29	34	26	64
12 - 18	41	29	35	27	76
6 - 12	40	26	35	24	75
12 - 18	40	28	39	25	75
6 - 12	40	29	37	30	59
18 - 24	40	26	37	24	90
12 - 18	40	25	39	26	59
12 - 18	39	27	30	25	85
6 - 12	39	34	36	27	73
6 - 12	38	29	38	27	46
12 - 18	38	26	33	25	51
6 - 12	38	26	37	28	66
18 - 24	38	30	35	28	68
6 - 12	38	27	35	29	70
12 - 18	38	26	32	25	55
0 - 6	38	29	38	27	64
6 - 12	38	29	37	24	80
6 - 12	38	28	32	25	83
6 - 12	37	26	33	27	60
6 - 12	37	28	36	27	50
6 - 12	37	26	36	27	35
12 - 18	37	26	37	26	40
6 - 12	37	25	33	26	41
0 - 6	35	21	32	22	60
Average		28.9		27.4	

*This crucible had iron-traces *inside*. Three other rings from this trench could not be accurately measured.

The total range for 53 Bongkisam crucibles is 21-35 mm. "large end" internal diameter. The 21 mm. case is unique, and *no others are less than 24 mm. internal* (just under 1"). If we extend this to the other end, and again exclude the same smallest crucible (at 22 mm. internal), we get a range of 24-35 mm. again. So over-all--with one exception--crucibles range in internal diameter from 24-35 mm. Or put another way, 90% of all these Bongkisam crucibles range over 23 mm. and below 36 mm. internal diameter. That would presumably be the width range of any ingots ("pigs") coming out of these crucibles.

The external diameter does not determine iron-form and varies more widely. We get a range of 35-58 mm. for the larger end and of 30-54 mm. for the smaller end. That is a total variation of:

Bongkisam: 53 Crucible Rings
(measurements in millimeters)

		Minimum	Maximum	Range of Variation
External:	larger end	35	58	23
	smaller end	32	54	22
	Total, external	32	58	26
Internal:	larger end	24	35	11
	smaller end	21	35	14
	Total, internal	21	35	14

Other measurements for this Bongkisam sample can be summarized:

(i) the crucibles were made at least as long as 133 mm. (no. 4 on main table at page 117);

(ii) the outer wall's thickness varied a lot, from 25 mm. to as little as 8 mm., and was itself tapered in nearly every case--only 4 out of 53 have the *same external diameter at each end;* and 3 of these are ones at the lower end of the external diameter scale (i.e., started with thinner walls at maximum);

(iii) there is *less variation in internal taper*--but this is almost always present and clearly part of the crucible working structure, tapering by 7-12 mm., normally somewhere around 3 mm., often less [cf. further at (f) below];

(iv) there is some tendency for crucible walls to be thicker on crucible deeper in the deposit--but this is probably due to more breakage of thinner ones deeper down, under depth pressure, as well as more overhead disturbance.

(c) Crucible Sizes from Buah and Jaong for Comparison

(i) Buah

So far these crucible observations are based exclusively on a part of Bongkisam. It is necessary to check for the sister site, Buah. For this purpose we took a small sample of fresh material excavated there in 1966. Here are the same measurements for all Buah 1966 rings, except for one which was not exactly measurable.

Buah, 1966: Crucible Ring Sizes (in mm.)

Trench	Depth (inches)	Larger End		Smaller End		Greatest Length
		External Diam.	Internal Diam.	External Diam.	Internal Diam.	
W/2	73 - 74	51	35	50	40	81
W/3	60 - 66	48	36	42	31	70
66/E	9 - 12	47	32	45	32	80
W/3	54 - 60	47	29	44	29	67
W/1	72 - 78	47	32	43	30	79
66/E	6 - 9	45	30	43	30	65
66/E	6 - 9	41	30	41	27	80
66/E2	6 - 9	40	29	40	30	54
66/E	6 - 9	40	27	38	25	80
Buah Average:			31.1		30.4	

This gives internal diameter ranges of 27-36 mm. for larger and 25-40 mm. for smaller ends. All but one of these, the 40 mm. smaller end, falls well inside the Bongkisam range; that crucible (first on the above table) shows a 5 mm. internal taper--compared with 5, 1, 0, 2, 0, 3, 1, and 2 for the others--but very unusually only 1 mma taper external. The external diameters are all well insaide the Bongkisam rangea

The odd "exception" is relevant enough--small though it be--as indicating again, from Buah, the aforesaid wide degree of variation, not *necessarily* due to rather crude potting methodsą though initially pointing rather that way; minor accident and error would anyway seem inevitable in this kind of undertaking?

(ii) Jaong

As all indications make Jaong the *earliest* of the three big delta slag sites (I.4), it seemed desarable to examine crucible sizes there and try for a time as well as a placea scale of comparison on these variations--which may enable other investigators to track down similar or identical crucible sizes and formulae. Jaong yielded 6 crucible rings in 1966, thus:

Jaong, 1966: Crucible Ring Sizes (in mm.)

Trench	Depth (inches)	Larger End		Smaller End		Greatest Length
		External Diama	Internal Diam.	External Diama	Internal Diama	
X/1	42 - 48	65	35	58	36	95
A/8	15 - 18	50	34	49	32	42
Y/3	24 - 36	50	30	45	29	44
A/3	9 - 12	48	33	46	31	55
A/8	18 - 21	48	37	47	32	52
A/8	12 - 15	46	33	39	28	56
Average			33.7		31a3	

The Jaong X/1 crucable (top of table) is a jumbo-saze job, 65 and 58 outside, 36 and 35 inside, the latter also a very low taper rate in a piece 95 mm. longa This is, once more, a ring that can be regarded as "exceptional." But (once more) the exceptional is also revealing as a clue to the whole iron operation here in the deltaa Looking more closely at the Jaong figures, they clearly tend consistently *higher* than Buah or Bongkisam. Such a trend cannot be estaba lished on so small a sample. We therefore re-examined a larger random sample out of the 1957 excavations at Jaong--chosen because the 1966 trenches continue from these in three directions and both lots therefore belong to one integrated sector of Jaong, thus reducing somewhat the possible variable factors from topographical differences. The new lot was of 19 rings from 10 trenches (all large). They were measured the same way as the rest, and all rings were kept out on work tables for checking until this study was complete. This added sample would insure that there was not simply some local or depth-chance factor in the four Jaong crucibled trenches of 1966.

Jaong, 1957: Crucible Ring Sizes (in mm.)

Trench	Depth (inches)	Larger End External Diam.	Larger End Internal Diam.	Smaller End External Diam.	Smaller End Internal Diam.	Greatest Length
B	18 - 24	59	35	42	26	60
D	6 - 12	57	35	50	35	41
K	0 - 6	57	38	51	35	83
C	0 - 6	57	34	44	31	44
F	12 - 18	55	39	50	35	74
B	24 - 30	55	35	45	33	50
E	24 - 30	55	35	46	35	56
B	24 - 30	55	39	50	32	70
E	12 - 18	54	32	52	30	40
E	18 - 24	54	34	43	30	44
P	24 - 30	51	35	43	35	67
B	24 - 30	51	34	44	33	42
P	12 - 18	49	30	46	29	50
H	6 - 12	48	34	40	31	61
D	6 - 12	46	30	38	30	81
A	0 - 6	46	33	42	30	67
X	6 - 12	46	30	39	30	45
B	18 - 24	45	32	43	30	38
A	6 - 12	45	32	42	31	53
Average			35.1		31.5	

If the above lot of 19 of 1957 is taken with the earlier 6 of 1966, for both series together out of Jaong we get:

Jaong: 25 Crucible Rings (in mm.)

		Minimum	Maximum	Range of Variation
External:	larger end	45	65	20
	smaller end	38	58	20
	Total, external	38	65	27
Internal:	larger end	30	39	9
	smaller end	26	36	10
	Total, internal	26	39	13

(d) Jaong's Larger Crucibles

Jaong and Bongkisam/Buah: Crucible Comparison (in mm.)

		Site	
		Jaong	Bongkisam with Buah
External:	Maximum	65	58
	Minimum	38	32
	Range	27	26
Internal:	Maximum	39	40
	Minimum	26	22
	Range	13	28
Number in sample		25	62

Jaong crucibles vary in *outside* diameter range much as Bongkisam and Buah, but:

--do not go so *small*, either inside or outside;

--go *bigger* (by 8 mm.) outsidea

This size difference is emphasized by the *largest external diameters:*

--15 out of 25 from Jaong are 50 mma or over at the larger end exteanally; compared with--

--only 8 out of 62 from Bongkisam and Buah with that diameter.

Again:

--0 from Jaong are smaller than 45 mmt maximum external diameter, whereas--

--38 out of 62 are that small (below 45 mm.) from Bongkisam and Buah.

The Jaong crucibles are thus larger and heavier, in these samples, than those from the two "later" iron sites. This is not just a matter of "clumsiness" or coarse texturet The *internal* diameter shows an even stronger distinction:

--only 4 out of 25 Jaong have an internal diameter below 30 mmt, compared with--

--48 out of 62 below 30 mm. from Bongkisam and Buaht

This is a difference of 16% for Jaong beside 77% for Bongkisam-Buah with minimum internal bore below 30 mmt So it appears that the earlier Jaong technique was to use considerably larger crucibles on aggregate. Though there is median overlap the majority of non-Jaong crucibles *fall below the smallest of Jaong in size.*

This relative "coarsity" of Jaong crucibles as regards bulk is also supported in the range of taper within each cruciblet A high proportion of 5 (20%) *show zero taper internallyŋ* though they are mostly small pieces; but 6 (24%) taper 4 mm.t--compared with 16% at Bongkisamt

Too much must not be made of such small scale, small sample differencest But there is enough here to show that at Jaong the cylinders were generally larger--although erratically so--representing in this sense a "rougher" technique. They were also a little sandier and coarser in texture (see below).

Three good reasons why crucibles might have become rather finer and smaller later at Buah and Bongkisam:

(i) More refined methods to meet a more exacting market; the larger the crucible the harder it is to heat evenly and work out well; the coarser the texture the less resistant to high temperature and load.

(ii) Decrease in supplies of more easily worked iron sources (IV.20).

(iii) Fuel difficulties as the area was increasingly worked (III.18).

It is difficult to imagine that any decline or change in clay could be operative here; nor any reason for reducing tuyère size in this way.

(e) Thickness of Crucible Walls

But there could perhapstbe a simpler trend underlying these differences, of themselves so small that they can only be reliably detected by millimeter measurement on sample series--and even then remain subject only to cautious generalizationt Over several centuries the local understanding of refining raw iron to steel improved in the delta, and with it the crucibles were themselves refined?

The particular concern in any clay artifact to be used for the purpose of smelting iron to produce steel must be the least possible thickness of the vessels' wall consistent with its retaining form when heated. The thinner the wall, the better the fire can be applied to the contents, naturally. The limits are narrow, howevert One early English crucible was 0.2" thick and an early Welsh one 0.08" at the top (our larger end) and 0.16" half way downt Discussing this, Tylecote points out that:

> A modern clay foundry crucible is never thinner than this, and the reason for the greater thickness of some of the more primitive crucibles is the poor quality of the clayt (130)

It is possible to examine this thickness factor more closely by simply analysis from thetfigures already given abovet

Subtracting internal from external diameters, as above listed, and halving the result, gives the wall thickness, approximatelyt In the following discussion where this would be, say, 4.5, it is shown for convenience in round figures as 5, the higher side of the half; fractions can be misleadtng at this level of precision, and with the walltby no means necessarily symmetrical even along any one cross-section (see Plates 7-10 for exact cross-sections)t

The last column in the following table compares thickness at each end, always realizing these are only "ends" in the excavational sense, very probably not on the original potter's product in clayt The top three numbers in brackets and italics in the last column are for eleven cases where

Bongkisam: 53 Crucible Walls, Thickness

Thickness (to nearest mm.)	Larger End	Smaller End	Difference in thickness between the two ends
0	-	-	3 (3)
1	-	1	14 (5)
2	-	3	15 (3)
3	1	4	10
4	1	10	7
5	7	7	3
6	15	5	-
7	7	13	1
8	5	5	-
9	6	2	-
10	6	3	-
11	2	-	-
12	2	-	-
13	1	-	-
Total	53	53	53

Jaong: 25 Crucible Walls, Thickness

Thickness (to nearest mm.)	Larger End	Smaller End	Difference in thickness between the two ends
0	-	-	2
1	-	-	8 (3)
2	-	-	3 (1)
3	-	-	2
4	-	2	7
5	-	2	3 (1)
6	2	6	
7	5	3	
8	7	7	
9	1	3	
10	7	-	
11	1	2	
12	2	-	
13	-	-	
Total	25	25	25 (5)

the wall is equal or thicker at the *smaller* than at the larger enda The smaller Buah series give results close to Bongkisam: larger end thickness all 6-9 mm.; smaller end all 5-8 mm.; and the difference all 0-3 mma, with 1 thicker small end (at 2 mm.). The Jaong series, 1957-1966, can be taken for direct comparison (see the second table on the previous page)a This analysis confirms a tendency for thicker walls at Jaong--though once again there is overlap, no rigid pattern, in conformity with the regular delta pattern of irregularity inside continuity.

Comparing the Jaong and Bongkisam samples as percentages we get:

Bongkisam and Jaong: Crucible Wall Thickness
(as percentages)

Thickness (to nearest mm.)	Larger End		Smaller End		Difference in thickness between the two ends	
	B.	J.	B.	J.	B.	J.
0 - 1	0%	0%	2%	0%	32%	40%
2 - 4	4	0	32	8	60	48
5 - 7	54	28	47	44	8	12
8 - 10	32	60	19	40	0	0
11 - 13	10	12	0	8	0	0
	100	100	100	100	100	100

Summariaed:

--58% of Bongkisam have the larger end thickness *under* 8 mm., cf. 28% of Jaong;

--79% of Bongkisam have the smaller end *under* 8 mm., cf. 52% of Jaong;

that is, Jaong crucibles are often thicker walled.a These are differences in inflection, not in consistent manufacture. The thickest of all walls, 12.5 mm., actually comes from Bongkisam, 18-24", as does the thinnest, 1 mma (but perhaps secondary from use) at the same deptha Bongkisam has 15% thicker at the *smaller* end, compared with 20% Jaonga

The generally larger overall *size* of the average Jaong crucible, earlier demonstrated, is consistent with the thicker walling; it may be necessary to have it so, sustaining larger internal diameter with greater thickness. The advantages of thinner walls might well require a narrower vessel [see (g) below].

(f) Taper

As no perfectly complete crucible has been recovered in twenty years delta study, the exact shape remains unclear. The basic shape is a cylinder. But this is far from *exactly* symmetrical, as the preceding figures have adequately shown. It remains, however, important to try and ascertain more precisely the axial character of assymetry. The crucible pieces under review nearly always show one end wider than the other, outside or inside, usually both. A single Bongkisam example has external and internal diameters the same at both ends; but it is also the *smallest piece (at 40 mm.) in the whole sample* [no. 51 on the main table at (b)] and would probably have shown some taper on a longer section. There is no such case of both-end uniformity at Buah *or* Jaong.

The easiest way to get a working idea of the degree of uniformity or of tapering is to compare the *inside* diameter of each piece, at both ends. This is the essential, working surface of cylinder. As Jaong crucible pieces are significantly wider inside than Bongkisam, they might be "expected" to show more liability to taper. However, these Jaong rings average consistently shorter than Bongkisam, which could mask this effect. The measurements for Jaong are shown in the first table on the following page. The degree of taper is not marked in this series. It certainly does not look as if well defined taper was a regular feature or necessity, but rather that it could be a by-product of the potter's hand, possibly accentuated by differential shrinkage from heating while in use.

At Bongkisam there is only one crucible with zero taper, however; and at the other extreme there is one (no. 12 on the main table) with 12 mm. taper, in a 77 mm. length, which is severe (for crucible). Jaong and Bongkisam, with Buah, may be compared summarily as shown in the second table on the following page.

Jaong: Degree of Taper in Crucible Pieces
(difference between diameter as between two ends)

Difference (in mm.)	Number showing this degree of difference	As percentage
0	5	20
1	5	20
2	5	20
3	4	16
4	2	8
5	2	8
6	0	0
7	1	4
8	0	0
9	1	4
	25	100

Jaong, Bongkisam/Buah: Crucible Taper Compared

Difference in internal diameter between two ends (in mm.)	Category of taper	Percentage showing this degree of difference at:	
		Jaong (25 pieces)	Bongkisam and Buah (62 pieces)
0 - 1	Negligible	40	42
2 - 3	Slight	36	40
4 - 5	Appreciable	16	13
6+	Considerable	8	5
		100	100

All three sites may be regarded as broadly the same, in that:

--over three-quarters show negligible to slight taper (0-3 mm.);

--under one-tenth show any considerable taper (more than 5 mm.).

An attempt to clarify this further by rejecting any crucible piece less than 80 mm. long, to give full taper potential, left 22 rings from the three sites:

All Sites: Taper in Crucible Lengths 80 mm. or Over

Category	Difference in internal diameter between two ends (in mm.)	Bongkisam	Buah	Jaong	All	As percentage	
Negligible	0	-	1	1	2	9	36
	1	5	-	1	6	27	
Slight	2	3	1	-	4	18	41
	3	3	1	1	5	23	
Appreciable	4 - 5	4	1	-	5	23	23
Considerable	6+	-	-	-	-	-	-
		15	4	3	22	100	

It is clear that these larger pieces show little more taper tendency than the shorter ones. Indeed, the "considerable" category is not at all represented among the longer pieces. However, the "negligible" category is less represented among the longer pieces. But the real differences are trivial, statistically. Moreover, this is broadly as much so for Jaong as for Bongkisam. Despite other and distinct tendencies to differ--usually in a large interior diameter and rather thicker walls at Jaong--the axial form of the crucible cylinder has not appreciably differed (visibly to the naked eye) over the whole delta operation.

This implies that taper as such was not *essential*, and perhaps not even particularly *desired*, in these crucibles; and that the effect may be fairly casual--for instance, a result of the way the crucibles were made by the potter in the first place or fired in the second (see III.19 below). The *look* of appreciable tapering on some crucible pieces, which validly distinguishes "larger" and "smaller" ends, is often due, in fact, to differences in the wall *thickness* between the two ends; this of course gives the effect of a difference in total breadth even though this is not the essential working (inside) one [cf. tables in (e) above].

All this points to a simple skillful method of potting, the sort of thing the wives of local Borneans could and readily would do. The absence of a closer standardization as regards *inside* width remains however a little surprising. Here of course we are seeing so little of the original crucible mass that other factors of importance may be totally unobserved--e.g., it could be that different crucible batteries or working groups or seasons or markets had a standard size and the variation is, on that scale, not so individual and casual as appearst

One can visualize that after the clay was rolled and kneaded wet, a stick was inserted and the whole rolled on a firm, flat surface, eventually completed with a stick of the size required for the bore of the final crucible.t

(g) Crucible Weights

Most crucible rings of moderate length are so affected by heat, corrosion or accretions (of "cake,t' slag, cinder, etc.) that it is impossible to imagine them to be close to actual weight. A small series selected as unusually free of such secondary effects was examined from this point of view; but the first in the table below *is* heavily charred and impregnated with metallic sheen at one end, with significant weight effect--it is included as one of the *longest* pieces recovered, nearest to the made, pre-breakage length (no. 1 below)t

Crucible: Some Weights

No.*	Site	Trench	Depth (inches)	Weight in oz.	Max. Length (approx. in inches)	Plate Illustration
1.	Bongkisam	II	8 - 12	16	5¼ (=133mm)	8
2.	Bongkisam	B8	0 - 6	9	4¼	7
3.	Bongkisam	II	12 - 18	8	4¼	9
4.	Bongkisam	II	12 - 18	7	3	-
5.	Bongkisam	II	6 - 12	5	3¼	10
6.	Buah	W/2	73 - 74	7	3¼	-

*(1) heavily fired, as above;
(3) one of the nearest to pre-iron, pristine condition;
(4) contains lump of metallic material as plug (increasing gross weight);
(5) one of the rare "waisted" rings [cf. (j) below and Pl. 10];
(6) one of the deepest intact rings, slight metallic encrustation on end and side.

Leaving aside no. 1 of the above six (for heavy encrustation) and no. 4, which is partly filled with metal, the other four rate around less than 2 oz. to 1". This is almost certainly still heavier than the original potted weight, we think. But taken as it stands, and allowing this figure as a rough average, then an unused 8" crucible might weigh 1 lb. maximum.[3]

(h) Crucible Capacity

Delta crucible was, in this view, primarily used to reheat and thus refine wrought iron (from the smelting of which comes most of the slag) into steel, although other uses are perfectly possible (see III.19). Economy of effort in this operation--for which they may have been among the pioneers in the area--was vital. The contents of a clay crucible will normally melt at about 1000°C.; after that are liable to resolidify rapidly due to the loss of heat through radiation. Fitting of crucible form (especially wall thickness) to fuel, fire position, human handling throughout all had to be meticuously right. This operation could not be nearly so rough and ready as the initial smelting; it was, in every sense, a process of refinement.

Whatever the outer shapes and sizes of variant crucible in the delta, what really counted was the contained space which could be reached by adequate heat inside. This consisted of a more or less symmetrical cylinder, as we have just seen. It is not difficult to calculate the cubic capacity of such cylinders, if we do not make unwarranted assumptions about original length.

Let us take two simple models, one for Jaong, one for Bongkisam.

For Jaong, we can conservatively postulate an average internal diameter over the whole length of at least 32 mm.; this means a 16 mm. radius. The longest piece sampled from Jaong is 95 mm.; most are much shorter. But it is almost impossible to put the original length at under an average of 80 mm. The cubic capacity of a cylindrical crucible at that length and width is:

$$\pi \left(\frac{22}{7}\right) \times r^2 \ (16^2) \times 80 = \textit{65,120 cubic millimeters}$$

For Bongkisam a rather smaller average overall diameter is indicated, say 28 mm.; but it is safe to postulate a longer cylinder in view of the measurements there (even though these probably only reflect different breakage patterns, and the same margin could be allowed for Jaong?). Allowing 100 mm. for original Bongkisam crucibles, we have:

$$\pi \left(\frac{22}{7}\right) \times r^2 \ (14^2) \times 100 = \textit{61,600 cubic millimeters}$$

The literature available on this subject uses cubic centimeters as usual standard. Put thus it can reasonably be said that delta crucibles have a capacity of somewhere around *60 to 65 cubic centimeters,* perhaps (and certainly sometimes) considerably more. Considering for a moment only the largest piece of crucible recovered from each site we have:

Bongkisam, no. 4, 29-32 mm. x 133mm.
= a capacity of *about 107 cubic centimeters*

Jaong, no. 1 of 1966, 35-36 mm. x 95 mm.
= a capacity of *about 96 cubic centimeters*

In brief, there were delta crucibles around at least the 100 cubic centimeter capacity markt It is likely this was a common form. It is most unlikely that any had a capacity much below 60 cubic centimeterst

This appears to be well above international prehistoric standards, although accurate information on this subject is extremely sparse. Tylecote has tabulated (138) most of the available data for Britain. None exceed 100 c.cm. and the majority are much smaller. The Asian and African material will be reviewed in later chapters. But the gaps in essential fact are very severe, and leave us in deep doubt.

In this situation, a simple, somewhat superficial little test was carried out on the delta spot during the 1966 dig. One pound weight of iron slag was poured into Bongkisam crucible rings. This 1 lb. filled *four* rings, respectively 83, 80, 79, and 53 mm. long, with internal diameters ranging from 24 to 28 mm.

Further research on this and related statistical and analytical aspects of iron technology are planned at Cornell, so that we will leave numerical analysis of crucible shapes and sizes at this point for the present and turn (in the rest of Part III) to wider aspects, briefly looking at more visual criteria and then at the whole pottery complex to which this belongs, inside a wider framework of attitudes and concepts of handling products out of the earth--clay, iron, growing plants.

(i) Visually Memorable Secondary Influences on Shape and Size

Without anticipating the important problem of how these delta crucibles were actually used in detail (to be discussed at the end of this Part, III.19), this chapter on shapes and sizes, which has necessarily been based on numerical data of measurement, requires a final section more general in character. Impossible of present measurement are those factors which can nevertheless be seen as affecting the crucible seen today: (i) taper affected by firing; (ii) size and thickness affected by body texture; (iii) side-effects from encrustation; (iv) breakage; (v) other discoloration. The Plates from page 169 illustrate these, too.

(i) Taper and Firing

The way the cylinder is heated patently affects the vessel as recovered after use. Many rings show signs of heat at one end (never both)t, and that this has warped or pressured the original shape, mainly by compressing the wall or narrowing the bore at that end. However--and rather surprisingly--in *no case* has this closed or even largely narrowed that end, though it may be pinched in through slumping of the walls. There are no recovered rings without *a clear hole at both ends;* and both ends within the range of *internal* diameters given in preceding tables--except (and the exception is important in another way) when some non-crucible material closes part of the cylinder internallyt In only one case is internal closure complete, in several it is partial [cf. (iii) below]. But even so, in no such cases is there any significant dislocation of cylindrical symmetry or the slight asymmetry earlier discussed as "taper.t"

It thus remains that there is no crucible with a clear-cut "bottom" or any piece itself like a "bottom," any form of seal-off, flat, curved, pointed, anything to enclose a cylinder endt So far as anyone knows, crucibles were either open at both ends or sealed with some other material (leaves or wood?) which was added just before firing and decomposed in the process or subsequently. The effect here described and those in the next three notes are all illustrated in Miss Fung's fine drawings which strengthen this text.

(ii) Body Texture

The texture of body is distinctly coarser in nearly all Jaong crucibles and includes easily visible spicules of other materials used by the potter to strengthen the clay ("grog"). Some of these additives are 4 to 5 mm. across and have not merged with the clay in firing. Fragments of pebble, quartz, reddish clay from other earthenware vessels, and in at least one case of *iron slag* are among items identified in positions on the body wall where they could only have been included in the vessel as originally made, could not be secondary accretions. No similar usage of such coarse tempering to earthenware pottery is known to us in the area. It was probably the original Jaong answer to some of the problems of wall thickness and strength under intense heat, already discussed.

Buah and Bongkisam crucible walls sometimes show such phenomena, but are usually much finer grained. These appear to have highly tempered with ground sand rather than bits and pieces, so that the texture is fine-ground by comparison with Jaong.

This aspect cannot be illustrated adequately by drawing, but requires microphotographic and X-ray studies impracticable for reproduction in this data paper. We plan to publish an analysis of this kind elsewhere, in the fairly near future.[4]

(iii) Encrustation Effects

Some crucibles have small encrustations or spots of iron slag, sometimes on the sides, more usually at the heat-affected end as described at (i). A few, such as one from Bongkisam B/2, 0-6" have less readily identifiable metallic accretions, not ordinary slag. But the commonest form, especially at Jaong over a wide area, is an accumulation of what has been earlier defined as "cake" (II.9.b), accumulated around the heat affected end, mainly on one side of it, so that it is attached to one-third or less of the outer circumference of the wall. Here again exact illustration and analysis is more suitably offered elsewhere.

A very few crucible rings are partially blocked by metallic material *inside* the cylinder. One, at Bongkisam II, 12-18" is wholly so blocked for about 2" (50 mm.). This effect can best have been produced by heating ferrous matter placed inside the crucible, discarded before the operation was complete--or perhaps because it was unsatisfactory.[5]

(iv) Breakage

The text plates show precisely the way in which every excavated crucible ring has irregular, terminal outlines, which could not possibly be inherent in the original pottings. All have been broken; and at both ends.

Where the recovered piece is a ring large enough to be critically studied, the breakage line is such as would be the result of a sharp blow, a little off right angles (85° or 95°?) to the long axis of the cylinder. But it is especially difficult to be more accurate about this, because so much secondary, after-use breakage is bound to have been involved by nature of the deposit's intensive prehistoric use plus protohistoric disturbances. At this remove in time it seems almost impossible to distinguish different kinds of breakage, though we are not without hope that a computer-type analysis may illuminate this important point further.

(v) Other Discoloration

In addition to and sometimes overlapping with the other four visual factors, there is a considerable range of secondary color effect on crucible bodies. At the "larger" end the crucibles are usually either a chalky off-white color or buff, but sometimes a dusky pink--clearly from heat. As the opposite, smaller end of the crucible is approached the color often modulates from light grey through the charred zone where it can be dull orange and black, with many color combinations and irregularities. These effects are the result of the heat, modified by later exposure, ground action and so on. The *interior* wall of the crucible as well as being normally regular throughout its length, is usually uniformly pale colored. But there is often some secondary color change on the interior wall along the greater part of the length retaining a buff appearance, then merging into an indistinct zone of discoloration with traces of possible metalliferous matter towards the smaller end.

III.16. RELATED POT FORMS

(a) Crucible in the Pottery Tradition

Crucibles, in the Sarawak River delta sense, are vessels of earthenware pottery, basically little or no different from the cooking pots and other artifacts in clay which have been made on a large scale, often with great skill and beautiful results, in this part of Borneo since well back into the Stone Age. The Niah Great Cave excavations give a series of radio-carbon dates for fine earthenware vessels before the Christian era, a whole assemblage of them--including large burial jars in three colors--before any significant iron, let alone iron *industry*, reached the island.

It is against such a background that the delta use of crucible has to be seen. R. J. Forbes considers it "quite probable that the earliest crucible" originated as a smelting device in a pot-making set-up; he continues (132):

> Both crucible and cupel were developed as the smelting, melting and refining of metals came to be more known and as the proper refractory ingredients were soon found in a world which had a thorough knowledge of the potterts art.

This art of the potter is something deeply implanted in Bornean culture. Like some aspects of native iron-working it still persists, dwindling, in the interior where communications make imported manufactures expensive. Until the last century a majority of the population made all their own domestic vessels from clays found often with difficulty and by mining--in much the same way and with the same geological craft which enabled them equally to seek out iron and (where they occur) gold or diamonds (cf. V.29 on how these were mined by Dayaks). It was normally the man's job to fetch the clay, the womants to make the pots. It is therefore likely that the delta cylinders were made by women, from clay which in this case requires no special search, since it is all around in the swamp [see further at (g) below].

Native potting was not confined to utility domestic earthenwares. Little, delicate pots were made for storing special foods and spices. Potlets of thumb size and less were made for funerary purposes, spirit offerings, etc. It was a liberal art, with a great variety of decorative patterns, mostly applied by paddle-beaters (handsomely carved).

But the techniques of the actual potting, especially of the firing, was fairly simple--and one of us has seen it done, often, in the interior during the forties and early fifties. The clay, some water to wet it, a round-stone to act as an anvil inside and a beater to knead from outside, a good pair of hands, good firewood, a really good hot open fire, properly controlled, out on the ground on a day with some breeze but not too much. That is all. No oven, kiln or wheel is needed here. Dr. Derek Freeman has published a recent account of an elderly sea-Dayak pot-maker which sounds very much like Spenser St. John's description of Kayan smelting (as cited in II.10.d) in manner of straightforward application: "material x heat = result." Both are crafts at their simplest, and there were once more elaborate versions; but the point is a fair one. Knowledge, spiritual aid, own judgment, experience, skill of a high order were always required, of course. But the actual *mechanics of the job* could hardly be simpler, once these skills were acquired and regularly applied (loss of regularity can be fatal; this has corrupted what remains of these and other native crafts in the past two decades).

Pot-making and iron-working (both smelting and later phases) have something else of importance in common. Both sets of operations involve an open hearth working out-of-doors; but something more intensive than just an ordinary fire: a carefully controlled, well-directed heat supply. In the delta context within Borneo it is easy to understand, even to identify with, W. Ruben's detailed 1939 study of the Asur, a tribe of smiths who inhabit the mountains of Chota Nagpur, India. The Asur were originally nomadic, staying up to three years at an iron ore *and* fuel place, moving on when these facilities were exhausted. They had no settled agriculture, but kept a few cattle. As Forbes put it:

> Ruben has proved that we have to do with a tribe that originally belonged to a cattle-raising culture. . . . . This culture is certainly connected with early metallurgy . . . also by the fact that they were the first to possess pottery. (70)

The crucible is thus only one in a family of artifacts made from the island earth. Its siblings include cooking pots, huge burial urns and tiny "finger potlets," clay beads, the curious "phallic tops" of lidded boxes [see (c) below], cooking stoves of clay (a "Bajau" specialty), spindle-whorls and so-called fish-weight or net sinkers along with the tuyère nozzles on bellows pipes in the forge earlier discussed and ethnographically described by Schwaner for the interior in the last century (Appendix B). Some of these other forms have more or less to do with the crucible and related iron technology in the delta sites. They must therefore be examined in brief. First a few words to indicate the scale of the delta earthenwares in general--since we shall not return to this group of artifacts in the later analysis of outside evidence by association (Part V of this paper).

(b) The Totality of Prehistoric Earthenwares in the Delta

The delta sites are rich in sherds of earthenware vessels, in the same general style as those of local manufacture excavated in neolithic cave sites in Southwest Borneo as well as those made in the interior into this decade.[t2] These represent what Dr. Solheim has styled "the Bau tradition" in pot-making.[t3] There is every reason to think most if not all of such earthenware was made in Borneo, though not all of it necessarily on the spot in the delta.

Prior to 1966 one of us studied and classified 82,350 sherds of delta earthenware. This was supplemented by a smaller study in 1966, which covers the main points for present purposes. The comparable figures for non-island, harder, higher-fired imported Chinese stonewares are given in parallel for comparison. Stonewares may here be provisionally taken as a very rough index of usages other thant simple earthenware domesticity on the site--e.g., burials, rituals or other occasions favoring more elaborate and "valuable" vessel materials.

Earthenware and Stoneware Frequencies, 1966 Sites (expressed as sherds *per surface square foot excavated:* cf. II.7.c for method)

Site	Excavated square feet (taken for sample)	Sherds per surface square foot	
		Earthenware	Stoneware
Jaong	367	1.0	2.7
Buah	130	14.6	8.4
Bongkisam	140	7.6	2.4
Maras (for comparison)	230	22.1	0.05

As if to please, Jaong's 367 square feet of 1966 actually gave up 367 earthenware sherds, compared with 1,365 stoneware. Of course these are only approximate indications; but they do broadly reflect the pattern checked over the delta years. The difference in density between sites can be misleading, in so far as at Buah a known stoneware sector (cf. 1955 and 1957) was re-excavated for a closer sherd analysis there (66/E:1): even so, at this known concentration of import ceramics, local earthenware easily predominates, at almost double.

The Maras hillside is not a major iron site, primarily a center for habitation--perhaps by laborers and traders living above the main workings down on the flatter land nearer the river and creek below. Jaong has a high ritual content, of a "primitive" kind, with which the largely T'ang stonewares there were in part closely associated. Comparing the ratio of earthenware to stoneware sherds for the sites:

Jaong	--	1:4	earthenware:stoneware
Buah	--	2:1	
Bongkisam	--	1½:1	
Maras	--	*ca.* 500:1	

Earthenwares do *tend* to occur deeper than stonewares, but with much variation. It has not proved possible to detect any major differences in the earthenwares as a whole over the delta sites and times, in size, style, shape or decoration. A wide range of forms is present. But these are not exclusive to any one site, level or period, so far as can presently be seen. They do, however, vary considerably in detail. Some of these forms are quite elaborate, as with the spouted drinking vessels (*kendi*). To quote part of the summary from the draft report on delta earthenware as a whole:

> It has emerged from the above that although the general "feel" of this delta earthenware is local and somewhat "primitive," it has not the diversity and intensity in shape of most late stone-age pot-making. This represents, in fact, the after-end of the stone-age and the impact of three products of a more advanced technical accomplishment: iron, stoneware and glass, all produced by high-temperature firing. Yet the earthenware went on. As regards decor especially, a keen vitality and huge production of this earthenware continued with no sign of slackening in west Borneo over the full time-span of the delta iron activity. In the last phases of Buah and Bongkisam such wares remain abundant and on Maras overwhelmingly predominant though

in rather simple form there (utility vessels especially). From start to finish:

(a) there is remarkably LITTLE distinctive change in the commonest shapes and sizes, though changes of detail occur;

(b) what does happen is that some sorts DROP OUT or decrease with time~~t~~-working towards a reduction and simplification which also continued *after* the delta to the present time.

(c) "Phallic Tops" or Handles

These interesting products of the potter's hand were first so described by our colleague Dr. Solheim from a study he made of sherds from the Tanjong Kubor headland country, close to Santubong, fully excavated in 1955.[4] In the last four years a lot more has been learned about the distribution and use of such lidded round boxes or pots, the tops of the lids shaped in this supposedly "phallic" way (see Plates 11 and 12 at pages 177-179).

The point of special relevance in the present context is simply that this unusual sort of pottery has now been identified beyond the delta up into the Sarawak River headwaters in prehistoric sites; and in an ethnographic context, as still being made in closely the same way by the Bajau peoples of Sabah, at the north end of Borneo. It is provisionally possible to correlate one source of these topped lids with the Bajaus, a people who have a prehistoric tradition of semi-nomadic life on boats along the coasts and among the islands as part of a wide mesh of inter-related folk reaching from Mergui and the Burma coast through Southeast Asia well up into the southern Philippines and eastward at least to Celebes, there merging into the Bugis. These are the people David Sopher has written of as "The Sea Nomads."[5] Their identification with this particular sort of pottery, if confirmed, would strengthen the view that some such mari~~t~~ time people acted as *carriers* in the rich trade which imported into the delta from no one "obvious" direct source.[6]

The function of these lidded, topped vessels is something of a subsidiary puzzle. They are so distributed that a more-than-functional usage is strongly indicated: for instance, four close to the Tantric shrine in the Z/1A-D sector at Bongkisam; or densely in the small Kubor headland cemetery, where at least 80 have been identified out of 33,250 sherds, i.e., 2.5 phallics per 1000 sherds. But nowhere are they wholly absent; Buah shows 3 phallics per 1000 sherds, including one in the major D/slag concentration; and the occupation, slag-poor site on the Maras hillside runs at 1.5 per 1000. We are tempted to suggest that they served originally in some way as reliquary receptacles for offerings of some kind, associated with the iron-work or with iron-workers (deceased?). In this, they may well parallel the lidded and truly phallic (golden *linga*) topped silver box in the Bongkisam shrine (V.30), which is much of the same size and shape; as also the curious faceted local stones and the carnelians to be noted presently (V.28); plus the surely sexual metaphor in a good deal of the Jaong rock-carvings (V.32).

Although the association with the Bajaus is remarkable in Borneo these earthenware artifacts enjoy a wider association, as well.[7] They recall, for instance, a good deal in the mainland literature of ancient China where similar things were ancestral symbols, *tsu*. This was interestingly put to the test when Dr. Cheng Te-k'un of Cambridge University visited Santubong at a time when the work-tables there were covered with phallic tops under study. He walked straight over to these, smiling delightedly--a smile of recognition. On the spot he recorded this note for our field log:

> *Knobs of pottery covers--*
>
> May be compared:
>
> (1) to those discovered by Andersson in Kansu in the 1920's, now in the Museum of Far Eastern Antiquities in Stockholm. There are three examples all published by him in *Bull. Museum Far Eastern Antiquities* (Stockholm);
>
> (2) to the *tsu* figures found in prehistoric and Sh'ang levels in North China, which have been published by the members of the Academia Sinica in their Journals, especially *Journal of Chinese Archaeology;*
>
> (3) to the Chinese and Mesapotamian pottery covers referred to by Li Chi in his *Beginning of Chinese Civilisation* (3 lectures, 1955?);
>
> (4) to the pottery covers from Lung-shan culture, published in Cheng-tzu-gai (1934).
>
> The Sarawak examples constitute more varieties of knobs, however. (C.T.K.)[8]

Professor Cheng's final remark reflects the indeed wide range of knob-forms. From these and other features, it is also evident that there is more than one source for the earthenware as a whole. At least two different clays are in use, one very gritty and baking red: though often the *same* shapes and styles are made. These would seem to represent a local, delta potting in the pale clay (including crucibles) and a redder ware perhaps carried in by maritime agents. These agents had contact with the mainland, probably fairly direct; the diffusion of the knob-lid would be a natural process--in either direction--especially if associated with early Chinese stonewares. Dr. Solheim, in his exhaustive examination of Kubor cemetery and other pots (which engaged him for much of one year in the Sarawak Museum), concluded that this earthenware assemblage originated from:

> at least two and probably three major sources, that it must have gone through a period of formation of some duration to be stabilised as it was at Kubor. For example, the phallic handles as a group changed little, yet they were probably quite foreign to two of the three probable sources. (1965: 61)[9]

That is, local forms developed out of earlier prototypes well before *ca.* 1200 A.D.

(d) "Phallic Pottery Objects" and "Net Sinkers"

The two terms here in quotes, "phallic pottery objects" and "net sinkers," are taken from the fine monograph by Rosa C. P. Tenazas (1968).[10] This Philippine inland lake site, not far from Manila, has many affinities with the late Bongkisam phase of Sarawak, including identical Chinese stoneware, some glass beads, iron slag. One of these affinities is the presence through the Sarawak River delta sites back to Jaong, as in Luzon, of quantities of the two sorts of artifacts in clay thus classified by Mrs. Tenazas who illustrated them as Plates 28-31 (4 "phallic objects") and Fig. 6 (5 "net sinkers"). We particularly refer to this paper because the illustrations are so good by Asian (or any) standards, and can therefore usefully be consulted by those interested (see also our Pl. 12b).

Both these Philippine categories of pottery artifacts are made of clay; so they are in the Sarawak River delta, where they are nearly always baked a deep red--like some of the phallic topped boxes and ordinary earthenware vessels already discussed. They are also patently thick-walled with a heavy admixture of sandy materials. There is a small hole right through the center of each. In Borneo we have long regarded them as curious, large "beads" for threading. Though generally cylindrical, they are very irregular in finish; and this is well shown for Luzon too, in Tenezas Fig. 6, where two of the sinkers have distinct bends in them. The equivalent pottery objects are not so clear cut in Sarawak--where there are an abundance of alternatives on this para-sexual theme, apparently lacking so strongly in the northern Philippines at that time. Indeed, having lately again handled some of those things in Sarawak and then on the Manila site and in the Natural Museum there,t[11] one wonders if the distinction is fully valid. Mrs. Tenazas' Plate 28 shows a "phallic pottery object" 3½ centimeters long with what certainly looks like a glans penis below a tapered, nozzle-like tip. But another, Plate 30, 5¼ cm., has this etched on the *bottom;* while her Plate 31 shows a 15-3/4 cm. biconal shape without any surface pattern, closely approximating a 4½ cm. "net sinker" shown in her Fig. 6.

In the text of the Manila report it is made clear that the phallic pottery objects occur "side by side with the traditional net-sinker forms," not infrequently but not necessarily "associated with burials,t' Mrs. Tenazas concludest[12]

> Because of the presence of holes they may either have been strung up and worn as pendants or used as regular net sinkers perhaps in the hope of obtaining an abundant catch.

An overlap in uncertain "function" is implicit in the above quoted sentencet From a comparative study in Sarawak, it is here suggested thatt

(i) the two categories (phallic and sinker) are perhaps variants of one and the same thinking in pottery terms and should be so considered;

(ii) there appears to be no evidence that such objects ever effectively functioned as net sinkers, either in Borneo or Luzon;

(iii) by the time of all these sites, there were better methods of sinking a net, anyway;

(iv) clay is a poor material for this purpose, in respect to weight and durability (especially in stormy seas with rough coral, rock bottoms);

(v) metal skills for making heavy durable sinkers were freely available locally in each case (in iron);

(vi) but lead is the ideal metal for this purpose and we know that lead artifacts were being traded throughout the area before 1300 A.D. (see V.29.b);

(vii) moreover, we have from one of the few at all adequate Chinese texts on the island during this period, the *Chu-fan-chih* as written by Chao Ju-kua and completed in 1205 A.D., a specific reference to lead sinkers being imported to the Philippines as a regular item of trade.

This last point (vii) is actually covered in a long extract from *Chu-fan-chih* cited in Leandro and Cecilia Locsin's lucid introduction to the Tenazas report. The relevant sentence lists sinkers as one of the *six important trade goods*, thus:

> In bartering, the Chinese goods consists (*sic*) of porcelain wares, black satin, coloured fabrics, variegated fiery pearls [beads?], leaden weights for nets and white tin.[13]

We have entered this by-way with both feet not only because these earthenware objects are a regular feature of the Santubong excavations, in association with the other pottery forms, including crucible (and of course, iton too); but equally because it is possible that their function has been misunderstood by all of us. Is it not possible that we are really looking at prehistoric versions of some sort of fine nozzle or pipe? In brief, one form of the missing tuyères to cap or tip (nipple) the bamboo--used to blow air on to the charcoal to help produce the high temperature with the necessary carbon monoxide both in smelting iron and in forging steel.

Until the whole assemblage is critically re-examined (and analyzed chemically) from this point of view, it will be unprofitable to elaborate. The forms are certainly unusual; so is a great deal else in the delta iron-working--and its possible cousins in Luzon and Malaya (Kuala Selinsing?).[14] Maybe some different process was in use then, now wholly extinct? It would make better sense, surely if these clay objects had some *land* use or value on the spot. There is nothing in the Sarawak context to suggest, even vaguely, that fishing was of such importance in the iron-working set-up. If net sinkers, why no fish hooks, for that matter? On the other hand, if these holed cylinders of clay had something--anything--to do with the crafts of the smelter or smith, their presence in burial settings as well as in iron-working centers would seem to make prehistoric sense.

The problem is interesting, and fully open to further investigation, which it deserves--both at the places mentioned and in other archaeological or ethnological positions, not here discussed. At the same time, the related pot-form called (in the Philippines) a "spindle whorl" might well be included in any such review. Some of these closely resemble the supposed net sinkers (cf. Laguna Fig. 5, upper row). No one has distinguished this category from "clay bead" in Sarawak, so far. The whole assemblage may have a simple origin back into the neolithic, where related specimens have been excavated in the Niah Great Cave. Like some of the stone tools--and underlying native psychology--these could readily be re-adapted to new, metallic conditions and techniques. Similarly, lead sinkers may have come to replace clay as part of another assemblage of metal objects, overlapping into other sorts of "rings," "bead" and so on.[15]

(e) <u>Clay on Potstone or Anvil?</u>

The delta sites carry many large rounded pebbles suitable as "anvils" held behind wet clay being paddle-beaten to make pots, etc. It is almost impossible, in this setting, to distinguish these from other large pebbles in the deposits (V.28.b). But a similarly shaped ball of what at first seemed to be clay was excavated away from the main iron sites up on the Maras hillside at 66/A2, 6-12", in an area of maximum local earthenware and only occasional import stonewares (see table at page 139). Our suspicion, as already noted, is that this hillside housed a native community settled a little away from the riverine turbulence of the iron-working; the families of men-folk engaged with metal down on the flats. The women stayed home and made, among other things, pots (and crucibles?).

This Maras stone is 3½" long, 2¼" broad, nearly oval, with smoothed rounded surface of a conspicuous general buff white coloration and clayey texture. It is heavy and the surface, when excavated, showed several distinct spots of ferrous material as well as clay--not slag encrustation but spicules of iron as an integral part of the whole. On washing and scrubbing, the layer of dull white clay--similar to that in the crucibles of Bongkisam at the foot of the hill--came off, revealing a rather browner color below, the surface still heavily pitted. This stone remains something of a mystery, unique in the excavations; perhaps a special (ritual?) thing for use as a potter's anvil? (See Plate 15 after Part V in next Volume.)

(f) Spouts, Nozzles or Nipples of Earthenware

Numerous small pieces of earthenware shaped as spouts or nozzles or nipples occur in the delta sites, including those without iron-working. Those from the headland cemetery on Tanjong Kubor somewhat puzzled Dr. Solheim in his earlier study. Some of these could easily be regarded as the ends of tuyères, except that they do not show signs of heat or metallic contact of any kind. Many also show what could be called "phallic affinities," within the broad framework of what is evidently a recurrent delta metaphor.

After careful study, the associations are considered insufficient to merit fuller treatment in the space available here. These and many other earthenware artifacts must be detailed separately in a later study. Meanwhile, Solheim's excellent analysis for Kubor is representative in a good many respects for the area as a whole, and is fully illustrated.[16]

(g) One Specialized Potting Technique

In minor experiments with delta clays for crucible purposes, we took balls of creek mud from behind Bongkisam and found they could be pierced through and rolled out laterally with a broom handle to produce, quite rapidly, a cylindrical lump easily shaped and potted. In doing this, T.H. was only repeating what he had often seen done by Kelabit potters in the far uplands of northern Sarawak who thus prepare local clay by stick insertion to roll a long cylinder *before* shaping their everyday cookpots. Not until we met Stephen Gasser, a Curator of Anthropology at the Field Museum of Natural History, Chicago, was the special significance of this potting technique recognized--except in so far as we ourselves felt some such method would be natural for the cylinder forms (cf. III.13 and III.15.f above).

Dr. Gasser has made elaborate study of native potting methods throughout island Southeast Asia (now in press). Asked, in Chicago, if there was any one thing he found uniquely peculiar to Bornean techniques, he promptly singled out the way the peoples of the Apo Kayan in northern Kalimantan first pierce the wet clay with a stick, and then roll it out flat by rotating this before the further (well-known) process of paddle-beating over a stone anvil. This is described and clearly illustrated for the 1920's by the Dutch H.F. Tillema. The Apo ("Upper") Kayan is the upper part of the Batang Kayan often referred to in this paper--the homeland of those Kayan and Kenyah peoples who excel in the arts of the smith.[17]

Here they smelted their own iron and made fine steel until recent times. It was from the Apo Kayan that these people spread westward into the Baram and Baloi river systems of northern Sarawak within protohistorical times. It was in the Baram that Charles Hose reported their crucible process late in the last century (III.13.a). The Kelabits were in part displaced northward topographically by the Kenyah and Kayans, who are now their immediate neighbors to the south and with whom they retain close socio-economic ties. That Kelabits use this same technique is not therefore surprising (photos of their procedure on file; account not yet published).

Beyond that, W. G. Solheim (who checked this part of our text) points out, from his special knowledge of earthenwares, that a similar piercing the clay and rolling-out method is used in northeast Thailand, in an area where he has found one of the earliest dates yet known for bronze-working in Southeast Asia. A similar process is found in the big pottery village just outside of Luang Probang, northern Laos, where the clay is not pierced but formed around a long *bamboo* cylinder.[18]

There is no need to labor the possible significance inside Borneo and elsewhere in the area, as having grown around the innovation required by making cylindrical crucibles (or tuyères) with the phase-out of stone-age potting and the advance of metal skills into melting (copper, etc.) and smelting (iron). It is too tempting, here, to avoid noticing a vigorous if remote parallel from West Africa, where the iron smelters south of Lake Chad are among the best and most highly organized in that continent. Writing of the remote inland North Nigerian village of Sukur in this decade, Hamo Sasoon (1964) describes the large (30" long) clay tuyères used as:

> . . . made by the smelter or his assistants from specially selected clay *moulded around a stick* and formed into a massive tube.[19]

It is also remarkable, in northern Nigeria, that these tuyères were pronouncedly "phallic" in terminal, "nozzle" shape. They were suitably made by the men only, though *all* other earthenware objects were potted exclusively by the wives of the iron-workers.[20]

On which last, if somewhat remote "phallic x masculine" note, we can suitably turn to a more vegetative aspect of delta metallurgy— the admirable bamboo.

III.17. BAMBOO

(a) Bamboo Pipes and the Nozzle Question Again

Bamboo is tough stuff when green, but grows brittle when long dry. In less than a decade it perishes in the open, but it lasts in recognizable though disintegrated form for centuries inside caves. It is present in early iron age horizons at the Lobang Tulang grottos and in the wonderful Painted Dave at Niah, in both cases associated with Chinese stonewares of delta types, glass beads, iron and human cremations.

Bamboo, known only as an expensive import in Europe and America, plays a tremendous part in the life of Borneo rural peoples, to this day. It is of concern in this Data Paper primarily as an easy on-the-spot source of conduit-piping, which can be and is used to carry air or water in almost any capacity from the hunter's blowpipe and the shaman's flute to the farmer's rice irrigation drain. Local use of this material was one of the things that most impressed early western visitors to Sarawak. One of the greatest of these, Alfred Russel Wallace, on his 1855 journey across the Sarawak River headwaters wrote of the frequent Dayak bridges with a mixture of admiration and lack of enthusiasm:

> Some of these were several hundred feet long and fifty or sixty high, *a single smooth bamboo four inches in diameter* forming the only pathway, while a slender handrail of the same material was often so shaky that it could only be used as a guide rather than a support.[1]

In Niah Caves, Sarawak, the edible birds' nest collectors use bamboo climbing poles of eighty-foot lengths, lashed together. A local tobacco box made from one internode measures 180 mmt (7") x 70 mm. internal and 85 mm. external diameter, near the largest size here.

The existence and abundance of bamboo throughout this island was of major assistance in developing an iron technology. It solved at once the main problem of carrying air from a bellows or other pressure source into the hearth, keeping the fuel glowing at the necessary high temperatures. All that was necessary to strike off one of the internal partitions (internodes). Lengths of up to 50 feet could be obtained in one stem. Shorter pieces could easily be joined. Narrower short lengths were readily available to be inserted into a broad section, for instance to turn the air down and focus on to the heart of a hearth, which is the way the Kelabit smiths of interior Sarawak treat steel over charcoal to make swords and axes now.

The narrow ends of green bamboo can operate for considerable periods under heat, though more briefly if directly pushed into the fire. Some of the best Borneo dishes are of foods packed in big bamboos and roasted direct on the fire, barbecue style. If kept away from actual flame, nipples of younger bamboo need only be replaced on bellows occasionally --and this can be done easily, as the smaller pieces are very abundant in most Borneo situations. A small "wall" of any suitable clay, to stick the nozzles through, is commonly used by Dayak blacksmiths, too.

It is possible, therefore, to direct air onto fire with natural bamboo, *without* using a more heat-resistant nozzle or tip--as fully described by Hose (194) for the Baram (VI.36.c). However, in the ethnographic literature there are a few references to non-bamboo "nozzles," strictly tuyère; the clearest is Schwaner's 1854 account for interior Kalimantan and Burns among the upriver Kayans of Sarawak."[2]

Some of the prehistoric iron work at Jaong, Buah, and Bongkisam may well have been carried on without the benefit of special nozzles. It is also possible that crucible forms were adapted or improvised to serve a dual purpose, as optional tuyères (discussed above). The speculation that smaller clay pieces might have been used as *tips* on the bamboo ends has just been considered.

(b) Botanical Considerations

It must be emphasized that for the iron-workers there were plentiful supplies of bamboo available in the Santubong area and southwest Sarawak generally, because some good scholars have apparently misunderstood the botany of these plants--a subfamily of grasses, *Bambusoideae*--in this part of the world. "Bamboo," like "mangrove," is not a single species, but a popular blanket term which covers a tremendous taxonomic variety. Professor Paul Wheatley has gone so far as to select an area in Malay Peninsular prehistory in preference to another because Arab texts mention plantations of bamboo and (he writes) "this plant flourished *only* on well-drained slopes such as those of the Tenasserim hills." Dr. Wheatley (1961) insists: "In the coastal lowlands it occurs only in isolated clumps."[3] Almost everyone else might have to accept the different opinion of the *Encyclopedia Britannica*: it occurs all over Southeast Asia (its optimum range) "*from sea-level to snow-line*."[4] Although *always* clump-prone, since it propagates by seed, division or cutting, bamboos of various sorts occur everywhere thatthe tropical soil is not permanently sodden wet. It is difficult to think of any relevant area which would be excluded for the reason stated from that distinguished arm-chair; certainly this cannot apply to Santubong, as we have obliquely seen in Mrs. Harriette MacDougall's eye account of everyday delta use in the last century (on our Title Sheet).

The Santubong area is well supplied with a wide range of bamboos, from very big to tiny--the logest are creepers, which can run over 200 feet. Despite modern substitute products the delta Malays of 1968 still recognize eight main kinds (*buloh* or *pering* with various descriptives.[5] To quote the co-founder of evolutionary theory again; he tells how "many journeys in Borneo" led him to "appreciate the admirable qualities of the bamboo," and concludes:

> The bamboo is one of the most wonderful and beautiful productions of the tropics, and one of nature's most valuable gifts to uncivilised men.[6]

(c) Other Relevant Usages of Bamboo

Bamboo is useful also in other ways which can be related to iron-working. Long pliable branches are used to work bellows by remote control (Appendix B). Bamboo can be cut into strips and bent over to form effective tongs or tweezers, suitable for lifting crucibles or metal lumps. It is often cut into short lengths for troughs, cups, and dippers, for instance to pour water on hot surfaces, as well as the longer uncut lengths serving as water conduits to working points, such as pottery-spot or furnace.

One is inclined to be impressed by one other aspect of delta bamboo. Much ordinary medium to larger size bamboo is just about the width of the crucible cylinders, while lengths roughly correspond to the natural internode distances in some live bamboo. The upland Kelabits use bamboo as an essential part of their elaborate clay-kiln process for making salt from the iodized springs which occur above 3000 feet in the far interior of Sarawak. After the liquid has been boiled in large cast-iron open bowls (imported from China) the mushy "bloom" of concentrated saline residue is transferred to single nodes of bamboo, about 2 inches in diameter, the internal wall forming a natural plus which is bored to drain excess liquid remaining in the mush prior to firing in the bamboo cylinders over a very hot fire. The bamboo is put gradually onto the glowing fire, but constantly turned (with bamboo or imported iron tongs), until it is completely burned off the by-now solidified salt inside, which has taken on the cylindrical shape of the bamboo itself--and is subsequently leaf-wrapped and sold all over the northern interior in this form.[7]

(d) Bamboo in Relation to Crucible Making

The technique of salt-making just described for the Kelabit uplands involves use of bamboo in a way closely related to the crucible *idea*, as a source of refining or finishing of the already treated but still coarse raw material won from out of mother earth. Moreover, this native approach suggests the possibility that bamboo might actually have been used in some such manner in direct association with clay crucible in working iron. If any kind of dual function --natural and potted cylinders of bamboo and clay respectively--ever operated, the vegetable part of it would have perished wholly in the flame plus time's decomposition.

Another and likely association at the delta level was the use of bamboo not only as a model, a native prototype for the cylinder form, but also in the actual making of the crucible or tuyère itself.

Good reasons for adducing use of a wooden core by the prehistoric potters have been given previously (III.15.f). What more "natural," in this Bornean context, than to roll the clay over *and with* cut lengths of bamboo? It would be possible, for that matter, to visualize shaping the clay cylinder over a core *inside* large bamboos which are irregular in cross-section taper--although we have no evidence or precedent for this suggestion other than the ingenuity of these people and the interchangeability both of their techniques and their theologies, grown like the great rain-forest trees, diverse and sometimes tremendous out of the past.[8]

III.18. CHARCOAL AND OTHER FUEL FACTORS

(a) Coal or Wood?

> Come to a hill crowded with charcoals,
> Come to a valley like a trough.
> This is the country of Selampandai,
> Who forges with clanging sounds,
> Selampetoh who forges with thumping noises.
>
> (*S.M.J.* 13, 1966: 235)

So goes one verse in the great Sea Dayak saga-chant for the Festival of the Whetstones, honoring Selampandai alias Selampetoh already known to the patient reader of this paper as "maker of man" and "god of iron" (see II.12). That first line echoes every sort of evidence, from folklore, ethnology, and archaeology: charcoal has *always* been the basic fuel at every stage of iron-working, from early smelter to contemporary sword-maker, throughout Borneo.

Some informed visitors to the delta sites have felt that such extensive operations required an extraordinary outside fuel, like coal. Coal is present in quantity, and near the surface at Selantik in the upper Sadong River of southwest Sarawak, where it was mined into the later part of the last century. But it is far up the narrows of a difficult river and a short stretch by sea (sheltered) thence to Santubong; there is no trace of coal in these or any other area archaeological deposits, and in any case coal is a poor fuel for smelting except under highly controlled and enclosed conditions, since "it contains harmful impurities, especially sulphur" (Coghlan: 107). It was not until the discovery of how to "coke" the coal that it was effectively used in western smelting, and that was around 1700 A.D.t--although it was the usual fuel in China much earlier, largely as a result of deforestation.

In parts of the western world fuel "must often have been rather a problem" (Coghlan: 106).t It can have been no such problem in the delta with its great areas of suitable charcoal-producing woods, which are still a lively source of revenue to the Sarawak government--exported to Singapore, Hongkong, widely regarded as among the best fuels in Southeast Asia. Charcoal is the ideal smelter's fuel; its carbon combines with the oxygen of the ore and metallic iron is released. As Coghlan sayst

> It is practically certain that the fuel used by the first iron smelters was charcoal, . . . in a simple reduction furnace the carbon of the charcoal will burn to carbon monoxide, and this gas will take oxygen from the ore to form carbon dioxide. . . . We know that charcoal was used from prehistoric times right through to the seventeenth century. (38 and 106)

The production of charcoal is a minor craft of its own, deeply based in Borneo cultures. Mangrove is the wood of choice in the delta--it is limited to saline mud-swamp land and cannot occur inland. A major study of mangrove charcoal was made by Dr. J. G. Watson of the Malayan Forestry Service, who followed I. H. Burkhill:

> Its calorific value is excellent . . . five tons of mangrove firewood are approximately equal in calorific value to two tons of Indian or Japanese coal, or to three tons of Malayan coal.[2]

(b) Available Trees and the Charcoal Economy

Mangrove is very unevenly distributed in Southeast Asia. For instance, there is *very* little on the east coast of the Malay Peninsula, but a great area of fine quality around Kuala Selinsing on the west coast, an important prehistoric site with many Sarawak River delta affinities (VI.33.b). On the west coast of Borneo two main mangrove strands of high quality are around Santubong and then again nearly 400 miles up the coast around Brunei Bay.

The best charcoal mangroves are of the genus *Rhizophora*, generally known as "*bakau*" in southwest Borneo. Other mangroves, notably of the genus *Bruguiera* ("*berus*"), give less good charcoal, but still superior to nearly all other common Asian woods. As forester Dr. F. G. Browne summarizes:

> (*Bakau*) principal importance is as firewood and charcoal, for both of which it is of excellent quality . . . (*Berus*) charcoal of good quality for inferior to *bakau*.[3]

Even after heavy exploitation in historic times, there are over 13,000 acres of controlled pure mangrove in the Sarawak River delta as of 1968. Rizophorous species over 18 inches in girth run 400-900 feet per acre, which foresters consider below an optimum yield of up to 1,500 feet per acre.[4]

This 13,000 acres is only the solid core. At least the same acreage again is of mixed stands, and there are extensive smaller mangrove outliers up the coast around Sematan to the west, round Muara Tebas and beyond to the east. In addition, there are other trees abundant in the immediate vicinity which give better than average charcoal--and much better than most readily available trees suited to this purpose in the interior. These include *Cerebra manghas* and *Xylocarpus moluccensis*, both swampy trees; *Trema orientalis*, a fast growing tree on river banks and clearings ("it was at one time regularly used in some countries for the manufacture of gunpowder" Browne: 360); seashore-loving casuarinas *Casuarina sumatrana* and *C. equisetifolia*, both of which are considered exceptionally good as firewood and very high grade as charcoal. Along the coast, too, *Excoecaria agollacha* is a tree of very wide distribution which would particularly be known to Indians, since it has long been a charcoal base there: in Sarawak it is the only wood used for the local manufacture of matches.

Relatively few hill-country trees are suitable for charcoal inland in Borneo and collecting enough even for use at a single village forge over 24 hours can be quite a troublesome and definitely a skilled job. In the delta, great stands of "living charcoal" are on the doorstep. Nothing of this kind applies in the rain forest.

In a situation such as that around Santubong in Sarawak (or Selinsing in Perak) it would be more economical to bring iron ore, even from a distance. To work ore in places without mangrove which would involve devoting much more labor-effort to obtaining the refined charcoal over the years. What this can mean is vividly illustrated from the same period, "late Bongkisam," but from the other side of the world. At Tudeley in Kent, England, between 1329 and 1354 A.D., a documented hearth was producing about 200 blooms of 30 lbs. each during the year:

> The main charge in working such a bloomery was the conversion of wood to charcoal which accounted for 50% of the running cost in spite of the fact that the timber itself came from the owner's estate. (Tylecote: 273)

(c) <u>Excavated Charcoal and a Radio-carbon Test</u>

Charcoal is almost everywhere at Jaong, Buah, and Bongkisam. But it is usually in very small, fragmented pieces, mixed up with the rest of the deposit, very rarely in sufficient recognizable quantities to enable a sample to be taken within any horizon, layer or trench sufficiently uncontaminated to insure valid analysis for radio-carbon measurement or other purposes. One of the rare exceptions was a cluster of charcoal in good condition at trench Z/3 in Bongkisam in the shrine sector, excavated on 12 July 1966. Unfortunately, this was rather higher in the deposit than one might have liked in this rubber-garden and modern cultivation area--9-12". However, in the absence of anything better, and through the courtesy of the Curator, Sarawak Museum (Mr. Benedict Sandin), this sample was submitted to Geochron Laboratories, Cambridge, Massachusetts, as this report was in draft, in the hope of getting an uncontaminated, pre-rubber date from its radio-carbon (C-14). Technical Director Dr. Harold W. Krueger kindly expedited the test at Geochron, and reported:

Sample:	Bongkisam site, charcoal (Z/3, 9-12")
Age:	635 ± 95--C-14 years B.P. = A.D. 1315 (maximum 1225 AD, minimum 1410 AD). [Geochron uses AD 1950 as a reference base.]
Descriptionn	Large pieces of charcoal. Some hair-like roots present.
Pretreatment:	The charcoal was cleaned and the rootlets were removed when observed. The charcoal was then treated with hot dilute CHl and NaOH to remove contaminants prior to analysis.
Comment:	It could be that the date is slightly lowered by some root hairs that may have escaped our examination. (H.W.K.)

Three factors should be borne in mind in considering the above Geochron result of 1315 A.D.

(i) The tiny rootlets mentioned in Dr. Krueger's report come from living vegetation in the rubber garden overhead, none of which can have been more than 60 years old; the effect, if any, of this intrusive material could be to make the analyzed date come out younger--that is, *later* than the deposition of the charcoal itself (which would thus be *pre*-1350 A.D.).

(ii) This charcoal was *above* the level of the stone platform in the adjacent shrine at Bongkisam (trench Z/1), to which we have elsewhere attributed a terminal date of *ca*. 1300 A.D. from purely stylistic associations (*S.M.J.*, 15, 1967: 216). The sample almost certainly dates after the shrine, and near the end of the whole operation.

(iii) Although the charcoal sample was specially selected from here as a sector of *minimal* site disturbance, this consideration cannot be ignored (see discussion in I.4.a).

The laboratory result to a gratifying extent supports the conclusions reached on other grounds, namely that:

(a) Bongkisam is a later site, peaking in late Sung and Yuan (*ca.* 1250 to 1340 A.D.).

(b) The whole delta activity suddenly ended before 1370 A.D.--the last possible date for the sample is 1315 + 95 = *1410 A.D.* but this is exceedingly improbable.

(d) Scale of Charcoal Needs

Mangrove and other first class firewood and charcoal fuels are abundant in the immediate vicinity of all the Santubong iron sites. Moreover, they can easily be carried in any estuarine direction through the labyrinthine web of rivers, creeks, cuts, and improvised canals which percolate the whole delta. This can only have been a major attraction to those setting up in the smelting or refining of iron here. Moreover, the Sarawak River estuary system offered both quick and easy access to the hinterland hill country, and achorage behind the coast against monsoon or storm on a scale seldom available anywhere else along the west coast of Borneo.

Even so, the scale of the iron-working with its calculated millions of pounds of slag (II.8) indicates a heavy run on fuels. If all this had been done in one short period, the good trees would soon have been exhausted--as has happened in some places elsewhere in Southeast Asia during *this* century. But these sites cover centuries; and it may well be that the yearly tempo of the work was set by fuel, among other factors. Working on a simple self-regeneration cycle, the delta mangrove (occasionally supplemented?) could support large-scale exploitation indefinitely--whereas most dry land trees raise much more difficult problems for cycle felling. It is even conceivable that charcoal made here may have been exported (as it is today); reversely, small craft could bring it from other points along the coast in case of a temporary, local shortage. Relatively little charcoal by weight goes a long way, as compared with the logistic problems of transporting firewood. Exactly how much is required necessarily depends on the ore and exact procedures used in firing. Here we come once more into areas of much uncertainty for the delta, so uncertain in this instance that it is unprofitable to speculate further at this stage.

Records in other literature--none for prehistoric Southeast Asia--give charcoal:ore ratios of from 4:1 to 1:1 and less. Proudfoot deduces from experimental data on another prehistoric furnace type:

> It is likely that in the original furnaces a smelt would have lasted about 24 hours, processed about 13.5 kg. and consumed about 45 kgs. of charcoal.t[5]

It should be emphasized that the preparation of charcoal on any large scale involves operations nearly comparable to those required for ore collecting. For small quantities, such as used by the inland blacksmiths of Borneo today, an improvised open hearth is, with skill adequate. For delta-style activities, it is quite likely that a separate though of course related network of charcoal producers, perhaps using clay kilns to get the necessary temperatures, served Jaong, Bongkisam, and Buah from elsewhere in the swamp sector. These would be centered where the best mangrove is concentrated, since transporting the green, sappy (the best for this purpose) wood before firing is a burdensome part of the local process as compared with a more leisurely carrying of the fired charcoal, easily handled in baskets or bags.

It is most unlikely that any prehistoric charcoal kiln would ever be relocated, over-grown for the past five centuries. But in hopes one might look for stations where charcoal was produced on the scale of many thousands of tons over a periodt Some estimates for fuel requirements so much higher than Proudfoott s above, giving (by weight)t

1 of smelted iront+ 4 of slagt= 15+ of charcoal

On this basis, and using the figures for slag already calculated (at III.8.j), these operations would have used not less than 200,000 to probably several *million* tons of charcoal--and, of course, an enormously greater weight of green mangrove (and other?) woods in the Sarawak River delta prehistorically.

Specifically for Bornean fuel usage we can only call on the scanty accounts of the previous century, of which the most complete (though confusing enough) is Schwanerts for Kalimantan, where he gives a ratio of ore to charcoal as 1:t10. This would probably be lower, however, with the high-quality mangrove woods not available inland, while the method he describes involves a carbonate ore smelted in an enclosed "oven" more elaborate than most described for Borneo--but perhaps more "economical" too (see Appendix B).[6]

III.19. HOW WAS THE CRUCIBLE USED AND FOR WHAT?

The question of usage for the pale clay cylinders was settled, in Chapter 13, provisionally in favor of crucible over tuyère, without excluding other usages as well, including tuyère. Now we have to try and answer an even more difficult question: how was the crucible aspect worked, and for what? This boils down to two more questions: (a) Smelting or melting? (b) Or refining?

(a) Smelting or Melting?

The evidence from the delta crucibles as excavated is--like most things in this vivid melange of prehistoric detritus--unclear, if not actually ambiguous. The way the cylinders were heated is obviously fundamental, but exact information on this is very difficult to reconstruct--and this has been the experience of archaeologists in other countries where this problem has been tackled. Even in Britain, where early iron technology has received major attention, there has been much disagreement on this. R. F. Tylecote, writing for that terrain only, sums up (130):

> Crucibles could either be used for collecting the products of smelting, or for melting metals for castings. Of the first method of use there is no evidence on British sites and it would seem that a clay-lined hollow below the fire was a more satisfactory way of collecting the products of smelting. Gowland came to the conclusion that many of the early crucibles used for melting had been placed below the fire because the external surfaces bore little or no trace of the action of heat, and they were thought too thick to be efficient for melting metal within a fire. However, an examination of the majority of British crucible provides sufficient evidence for the external application of heat, and both Moss and O'Riordain have felt that Gowland was wrong.

We have already touched on the parallel traces of heat action on the delta cylinders, where it is nearly always apparent and sometimes very conspicuous (III.15.i). Some further data for a few specific examples can usefully be added here.

Some crucibles show traces of burnt impacted sand on their surfaces, acquired after the actual potting of the form. In one important example, from Buah, 66/E at 24", a ring was excavated with a complete block of burned sand forming a collar about 2 inches thick; the larger uncharred end runs from light grey to pink; the ring of burned sand at the charred end is a deep purple color, flecked with pieces of irona

In June, 1952, at Jaong B/2, two complete base rings were recovered, placed in a sort of earth collar *side by side*, 6 inches apart. Other examples show iron encrustations as if two crucibles or their contents were closer than this and had actually been in lateral contact--notably Bongkisam II, 12-18", 1955. There also were some *laterally* burned (over part of the wall but not at the end) cylinders in Bongkisam J/4, 0-6".

Similar cases of cylinders recovered with heavy heat effects include:

Buah: W/2, 73-74"
Jaong: 57/B, 24-32"; C/5, 0-6", 6-12"; E/1, 18-24"
Bongkisama II, 12-18" (several)

The evidence strongly indicates that in all three main sites the cylinders were at one stage held in place by a ridge or wall of molded soil or clay, often more than one together in line. Inference from the delta examples indicates that this holding collar was usually between 50 and 60 millimeters thick, though this requires further verificationa

At Jaong, a series of the larger, coarser earthenware rings typical of that site and recovered in rather good condition, show something different again: a tendency to heavy caking of cinder and some metalliferous material around one end of the cylinder but only at one side of ita Several of them located in situ in 1957, variously at 0-6", 6-12", and 12-18", consistently have this kind of accretion 3 inches across (at right angles to the cylinder axis) and for about 2 inches up the outside wall, but adhering to this wall at the bottom for not more than oneathird of the cylinder's circumferencea

In at least nine-tenths of all cases, there can be no doubt that heat, naturally enough, was *primarily concentrated and directed at one end* of the crucible, normally the one which is now narrower in diameter; and possably from this side with air blown into the crucibleas contents laterally? There are no crucibles showing charring, metal impregnation or encrusaation *all over* or for any large area *all round*.

One other relevant feature, rare but hardly accidental, is a pinched *waist effect*, such as that shown on a Bongkisam

II 6-12" (illustrated at Pl. 10). The waist is only two-thirds inch deep, and runs around the circumference very unevenly. The whole wall to one side of it charred and blackened by metallic impregnation; the other side has baked dull pink patches over the buff-white clay body; the waist itself is rather whiter. This waisting could reflect some band of another material used as a sort of "collar" for the crucible (or tuyère); or alternatively, though very doubtfully, the effect could have been achieved by the potter (e.g., such a waist would facilitate lifting the crucible?).

Such are the continuing challenges of this complex material. One is left with the definite feeling that although the cylinders themselves have remained rather markedly consistent in style through the delta period, the handling of them may have changed or been varied to quite an extent. Different ways of arranging them in the fire were tried? Maybe there was no set rule--or, again, probably more than one usage for the same cylindrical tubes. This brings us back to the basic question: was the (main) usage for smelting ore or melting the product of smelting?

The British experience of "no crucible," already cited, has of itself no automatic validity for Borneo. Moreover, we have Everett's unequivocal first-hand sight of crucibles at Santubong (cited in III.13.b) plus Hose's 1912 emphatic and twice-stated view of the crucible with northern Kayans, which starts with "smelting is performed by mixing ore with charcoal in a clay crucible," and concludes "the crucible, having been brought to white heat in the furnace, is allowed to cool, when a mass of metallic iron or steel is found within" (full text in III.13.b). That last phrase's "or" gives some cause for unease. There is a biggish difference between metallic iron and *steel*. There is always the worry that Hose is not describing what he saw with his own eyes, in this unique (for Borneo) contemporary case of crucible used in primary smelting. In this connection it must be noted that in the same work, which was co-authored at a distance by famed psychology Professor William MacDougall, there is an amiable photo of Kelabit blacksmiths at work. There is nothing in the caption or the text to suggest that this is not an authentic picture of a Kelabit forge (making tools from steel). At the time that photograph was allegedly taken, the Kelabits came down to the coastal plain to trade but no white man had entered Kelabit country. Hose himself never got there. And to anyone who knows the Kelabit uplands and their smiths it is painfully clear that the whole thing is posed; indeed faked. Quite apart from the workers' postures, the setting is on a kept lawn such as cannot exist inland but is usual on a government station in the coastal lowlands (the only then such stations). Coconuts, unable to propagate in the uplands, wave frondily in the picture's backgroundt Could Hose in his text have confused or did he merge two processes--smelting ore and crucible refining the iron products? Or see both going on *at once* and *not* recognized the difference? Yet it seems unlikely.

On the other hand, the really quite intricate association of crucible and iron slag everywhere in the delta (as fully proven in the previous chapters) might well be taken as pointing to a direct use of the crucibles in *smelting* the ore. The idea cannot simply be discounted--along with the distinct possibility that crucibles were used in *more than one way* (or as tuyères too) at that time--despite the fact that several other ("earlier") travelers in the northern interior describe different and broadly simple methods of smelting, based on an open hearth, such as that postulated for the delta, but without benefit of crucible.

Here the early Chinese (pre-Christian and long pre-Moslem) evolution of a technique for smelting iron in crucibles would be significant. This process, so well described by Dr. Joseph Needham (14) involved very large cylindrical crucibles fired with coal from the fourth century A.D. in banks of hundreds at a time; this bears little direct relationship to anything imaginable in the delta. But the evidence at least for indirect contact with China is so very strong in the delta stonewares, etc., that there is a quite distinct possibility of some emphatic influence from this source.

Although the amount of crucible clay in the delta deposits is certainly impressive, and runs into millions, a simple calculation--which we will spare the intelligent reader here--could serve to show that there is too much more slag, that this slag could not have all been produced by this *few* cruciblest Not only numerically, but in cubic capacity, it seems impossible that this bulk of slag could have come out of a *purely crucible* process, leaving only that amount of crucible (roughly one-twentieth of the slag by weight)?

(b) Melting?

If smelting is unacceptable as the main, primary explanation for the crucible presence at Jaong and Bongkisam, what then of melting? Melting in a crucible from the smelted wrought iron is the basic process in producing *cast* iron. This trend started long before Jaong, in China. That land was centuries ahead of the rest of the world in this development, which involves re-melting the smelted product at high temperatures and necessarily with fairly sophisticated equipment, such as the enclosed blast furnace. There is no evidence of cast iron having been produced at any time in Borneo. To this day the inland people can make the finest steel *parang* swords but depend on Chinese imports for big cooking vessels and tripods of cast iron, which is much more brittle (and so less suitable for tools) but where liquid can be elaborately shaped by casting. It should be emphasized here that no mold for *casting* has been recovered in the delta. These *are* found at Chinese foundry sites.t

(c) Refining?

So we are brought, albeit hesitantly, to a third possible answer: that the crucible treatment was of iron after smelting, not to liquify and cast it but to refine it from the raw wrought iron form on into malleable steel. To quote Dr. Needham (14) again:

> In Asia [other than China] events had taken quite a different course [from the early Chinese]. In India, apparently, from a very early time, steel had been produced either from bloom iron or directly from black magnetite ore by packing it in refractory clay crucibles together with a mass of chips of particular woods and leaves of special plants. This empirical method delivered exactly the right amount of carbon to the iron, and the so-called "wootz" steel which it produced enjoyed for many centuries a world-wide renownt

It is in that "Indian" direction that we should look for one main clue to the origin and development of the delta techniques. The presence of other "Indian" influences (cf. V.30)--balancing that of the Chinese artifacts--must at all times be borne in mind along with the vital role of an indigenous effort. There is a good deal that indicates development of a "*wootz*" type of operation, in locally modified form, to produce malleable steel for tool-making as well as the ore itself by initial smelting. Sea Dayak folk-lore is full of relevant references, dating back up 30 generations or more, to the making of steel in four forms: *kemuja*, the best, sharpest kind; *besi brani*, "the brave iron," so strongly magnetic it picks up and "defeats" other iron; *besi belai*, "the expanding iron," readily hammered and thinned out when red hot; and *besi mata*, "unripe iron," which is inferior and easily cracked, used for nails and bladeless things (cf. cast iron?). In the greatest of all the Dayak chants for Gawai Burong, the Hornbill Festival (for the human heads; the text in Iban runs to 240 pages of typing), Tutong, the mighty blacksmith leader of the human spirit's other world and brother-in-law of top warrior Keling there--"the creator of iron" Selampandai, is in the other world of the *gods*[2]--is acclaimed as the cleverest in forging steel blades. At a late stage in these tremendous rites comes the *bededjang* ceremony where the shamans sing "to forge spiritually (*ngamboh*) the war knives of the (human) hosts" and for long cadences the refrain goes in this way:

Fell the ironwood tree with sounds,--
We are starting to forge.
Who then is the chief to be asked to forge?
"Let me," says Manggang, evil hearted bachelor.
"Let me" says Antu Inu Setauk Tui, a demon.
Who among us is able to blow the bellows?
"Let me" says Minggan who comes from the bright moonlight.
"Let me" says Minggat who comes from the yellow-flash lightning.
Who among us is able to temper the knife?
What do we use for the smiths bellows?
Let us kill those in the upper Kayan river [Kalimantan]
Let us use an ancient skull.

The singers range into every detail of an iron technology no longer known to the living celebrants in the long-house night. They are asked what the spirits use for the bellows (*puputan*), the clay fire wall protecting the bamboo airpipe (*siong*) from the fire's burning (*teladok*), for the piston, the blower, the anvil, the hammer ("let us use elbow and wrist"), cooling trough ("the belly of the ancient dead") with water ("the blood of a Punan child"), charcoal (*arang*) and pincers for handling the hot iron (*sepit-api*). Once the parts are thus assembled and invoked, the whole process of working is gone through in ecstasy, culminating in rhetoric like this:

Behold the iron is shining red,
Like the back of a cooked crab! . . .
Behold the steel of the crooked (*lambak*) knife is expanding,
Like the growth of a flower . . a
Then tap with a hammer,
Like the rattling sound of a woodpecker holing the tree branch,
Hammer it like a rich merchant,
Who hammers the sterm of his boat [because as he holds the tiller it clacks against the thwarts]

After many minutes of this verbal music:

> We end our forging works . . .
> To start to temper our weapons . . .
> Temper it yellow like the edge of a bird's beakt. . .

No wonder then in this belief that when the shaman has finished doctoring a sick person the patient must bite on a piece of iron to strengthen his soul for final recovery; or that a baby dying without having touched steel cannot enter the other world--an ultimate tragedy, but useful also in the abortion of unwanted bastards by unmarried mothers who deliberately deprive them of this contact so they lose both mortality and immortality!

Much in this astonishingly deep folklore has an Indic quality, in the view of Mr. Benedict Sandin, now Curator of the Sarawak Museum, who has transcribed and now translated the above (unpublished) and many other Dayak texts. The pantheon of Sea Dayak gods and spirits would indeed appear to carry strong tones of a Hindu-type theology absorbed into Bornean ecology and mythology (see, for instance, the heavenly genealogy given previously in II.12.b). The literature of the Ragvedic Age is rich in parallel iron mytho-technology from which M. N. Banerjee has concluded that steel was then being made.t[3] Later, the Upanishads memorialize the smith using a technique which R. J. Forbes has described (437) as "a marvelous example of the possibilities of primitive technique" at the beginning of the Christian erat

The wootz steel from India was traded throughout the ancient world, including to China. This is closely related to the damascene process for producing wavy lines in blades of swords and other artifacts, which early on became of almost obsessive esteem all the way from the Middle East to the Javanese *keris* dagger, and is closely related to the Kayan-Kenyah inlaid *parang* swords of central Borneot But before becoming ensnared in consideration of this fascinating but still almost uncharted field in Southeast Asian prehistory, we will close this part of the discussion with the wise weighty words of Coghlan, as ever much to the point on this subject:

> Finally, some reference must be made to the various damascene processes and their relation to wootz steel of ancient origin. This is a complicated matter which has occasioned some measure of confusion in archaeological literaturet (155)

(d) So What?

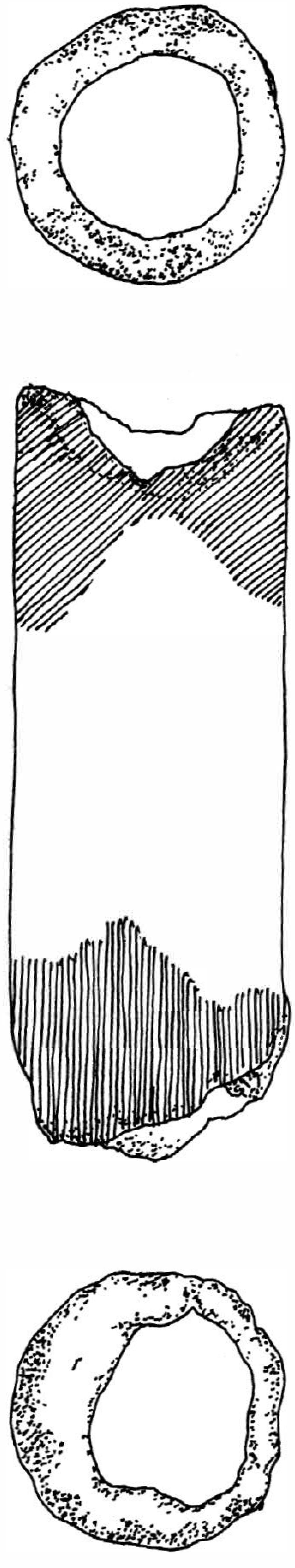
We are left in a cleft bamboo! No one simple answer to this delta question seems convincing. A sort of multi-answer is in somewhat confusing order instead. If forced to stand up and be counted, blushing we cast a first ballot vote for crucible use here in connection with carburizing steel from wrought iron, in a partly "Indian" but perhaps far-back "Chinese" influenced tradition, modified in local ways still unknown; and only likely to become known by excavation at a much less disturbed open site elsewhere in the archipelago (in a small island off southeast Borneo perhaps; or even in a large network of caves with easier access to the sea and other rivers than Niah, such as are reported in the Barito-Kapuas drainage of Southern Kalimantan)!

Whatever the method, these crucibles would produce solid cylinders of metal, little or not at all pitted on the surface, with a diameter between 22 mm. and 32 mm. The earliest ones, from Jaong mostly before 1100 A.D. as thick as 39 mm., regularly over 30 mm. The latter ones from Buah and Bongkisam narrower: 90% at these two places less than 30 mm.

But as so many variables are involved, let us be satisfied to say that what the delta produced over this period was a cylindrical ingot *approximately one inch* in diameter, often but not always 1 to 3 mm. narrower at one end than the other.

These ingots would have been at least 4 inches long. It is very unlikely the largest crucibles were more than 10 inches, probably nearer 7 inches. Beyond that, problems arise in handling the wet clay and keeping it symmetrical and firm, as well as in firing. The best we can do is settle for: probably within 4-8 inches. Perhaps now something of this shape and kind may be traced out elsewhere, including in other museums? From the inadequately examined literature, all we can find is a reference to "iron, presumably in bar form . . . used by Chinese traders as an article of barter in Sri Vijaya" (Paul Wheatley, 1961)[4] and this for a later date: also to complete the cross-ways of contact confusion:

> The Malays of Brunei and the other coast settlements have, of course, used iron, and perhaps to some small extent forged it, since the time when they adopted Arab civilization; but they have not at any time practised the smelting of iron ore. Between three and five hundred years ago the principal currency of the people of Brunei consisted of small oblong flattened pieces of iron known as *sapanggal* (*about 2x1x¼ inches*) bearing the Sultan's stamp. This iron was probably obtained from Chinese and other foreign traders, and was worked up into implements. (Hose: 193; see also end of Appendix E.)



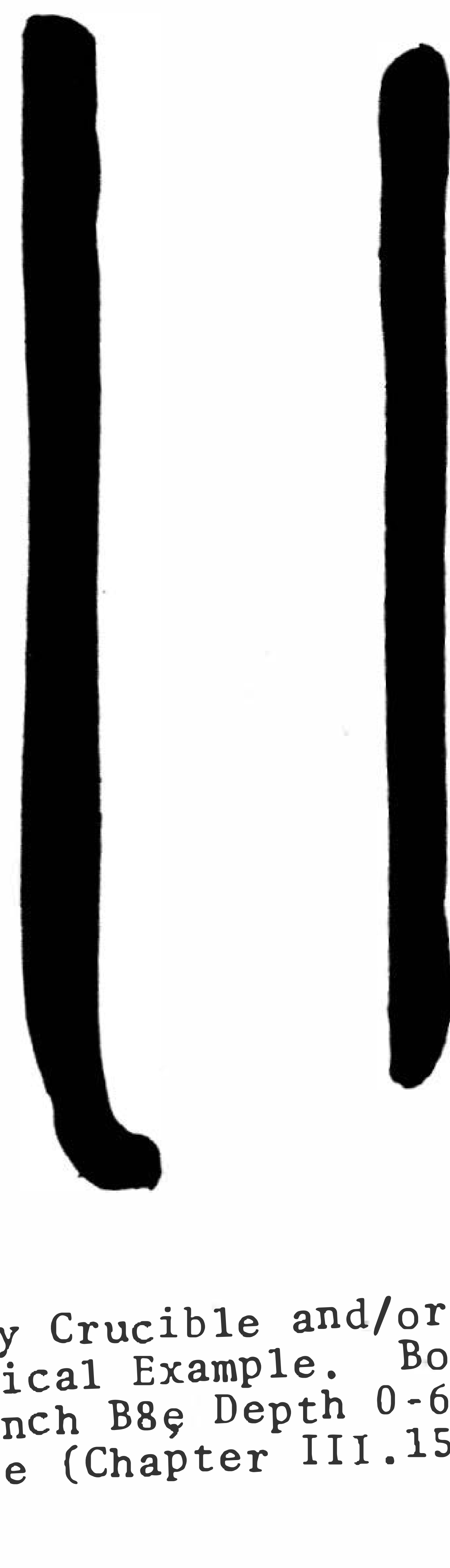


Plate 7. Clay Crucible and/or Tuyère. Typical Example. Bongkisam, Trench B8ç Depth 0-6". Natural Size (Chapter III.15.a).

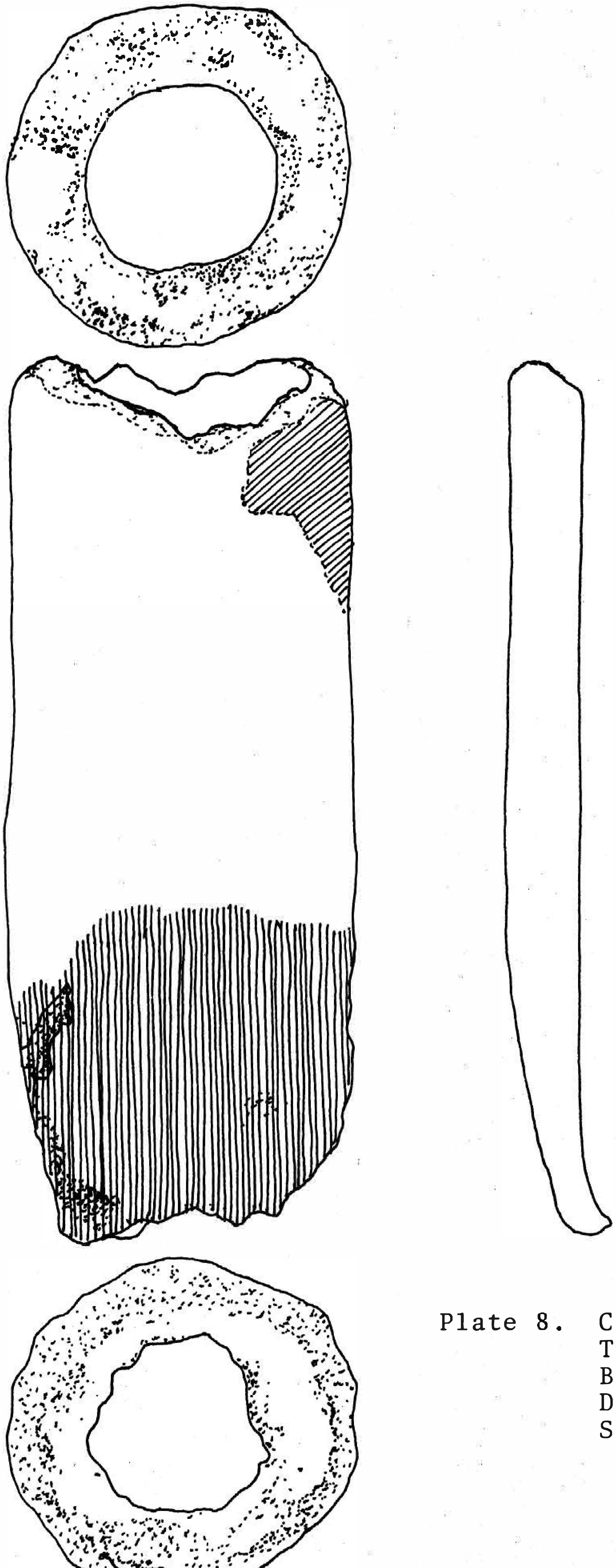


Plate 8. Clay Crucible and/or Tuyèrea Typical Example. Bongkisar, Trench II, Depth 6-12". Natural Size (Chapter III.15.a).

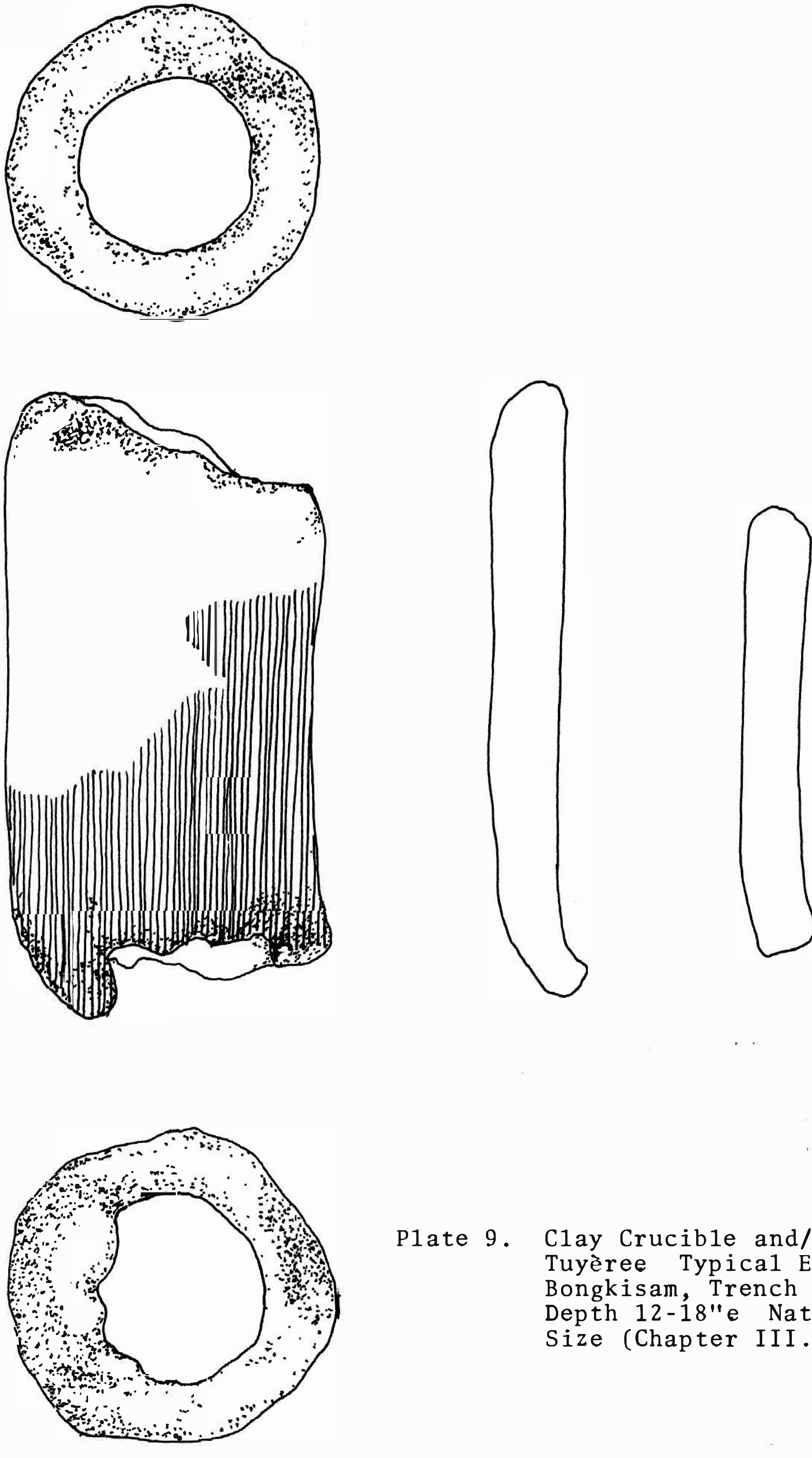
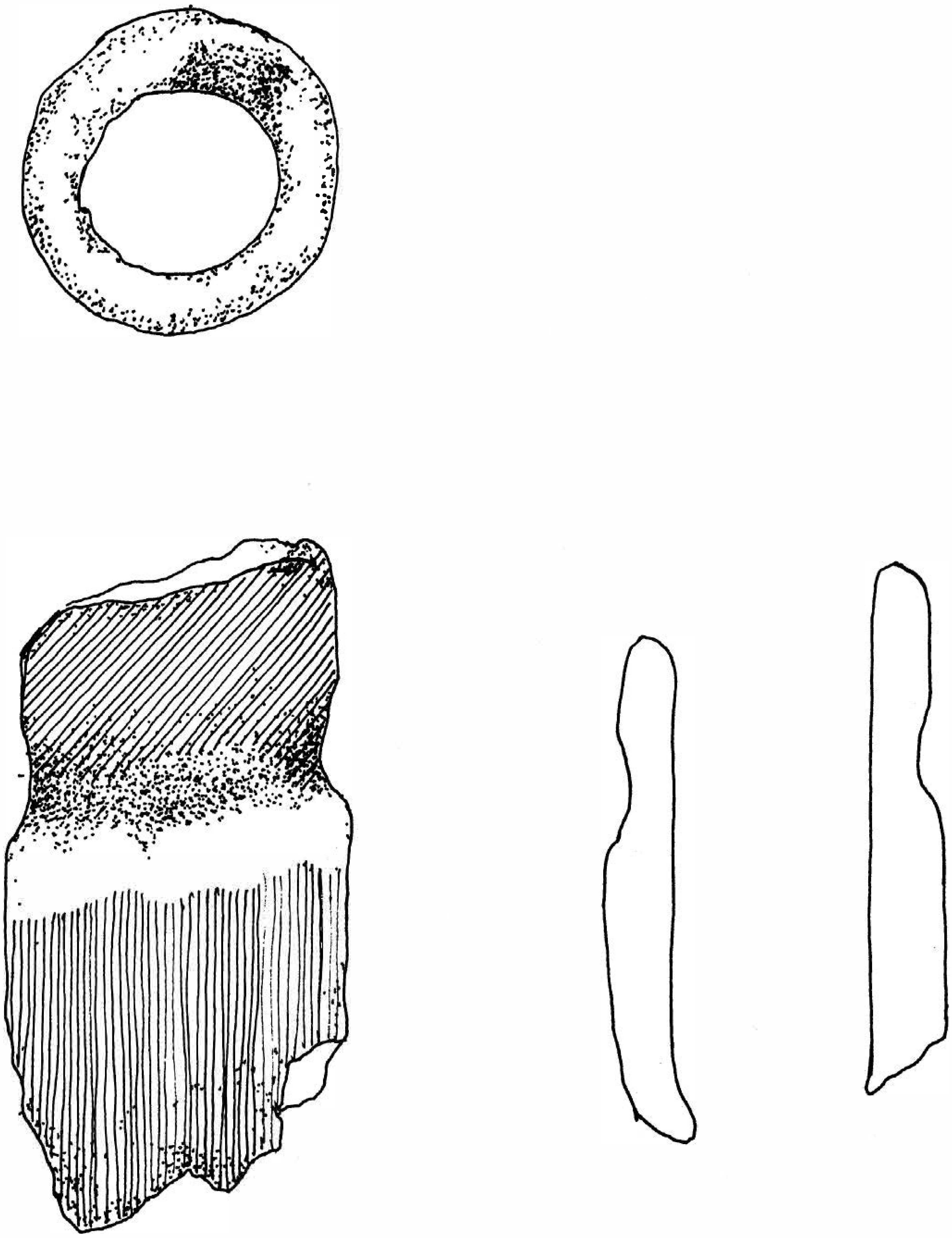


Plate 9. Clay Crucible and/or Tuyèree Typical Example. Bongkisam, Trench II, Depth 12-18"e Natural Size (Chapter III.15.a).



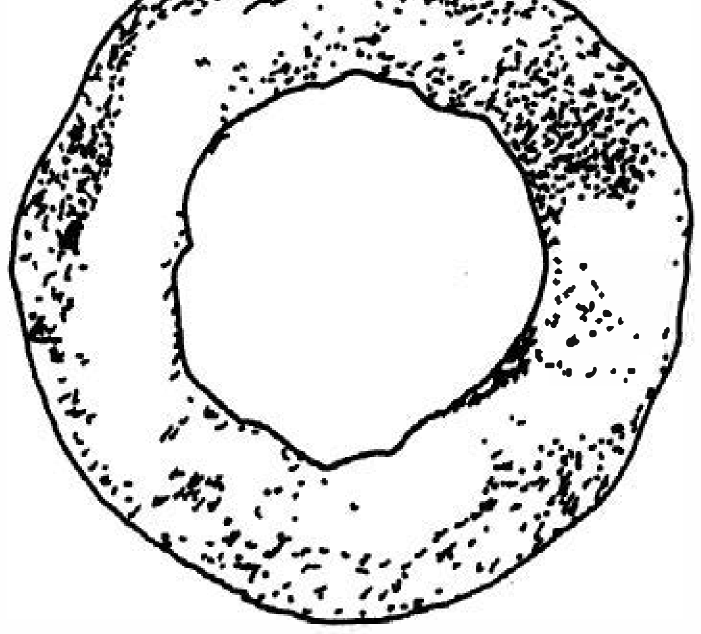


Plate 10. Clay Crucible and/or Tuyère. Waisted Effect is Exceptional. Bongkisam, Trench II, Depth 6-12". Natural Size (Chapter III.15.g).

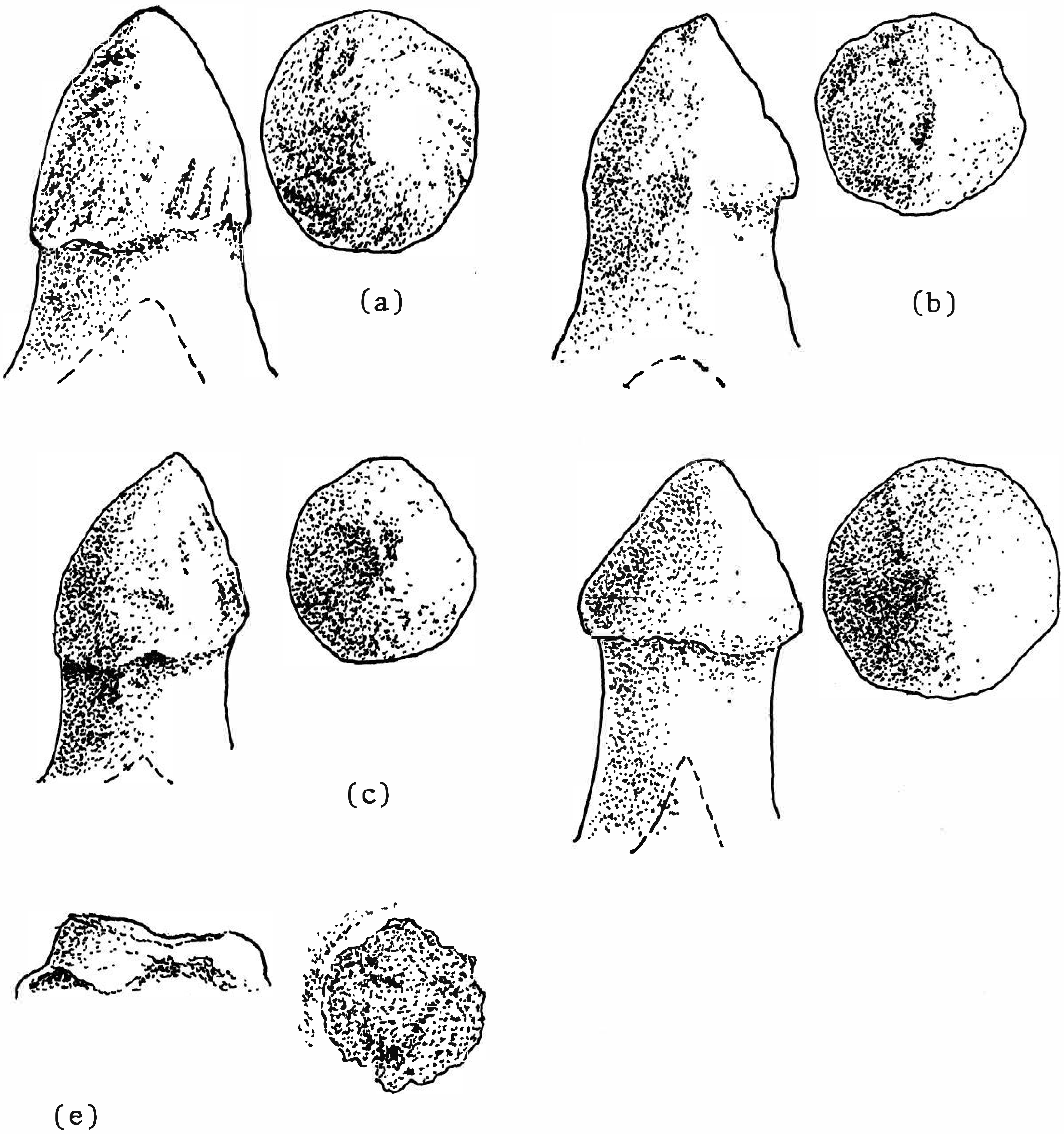
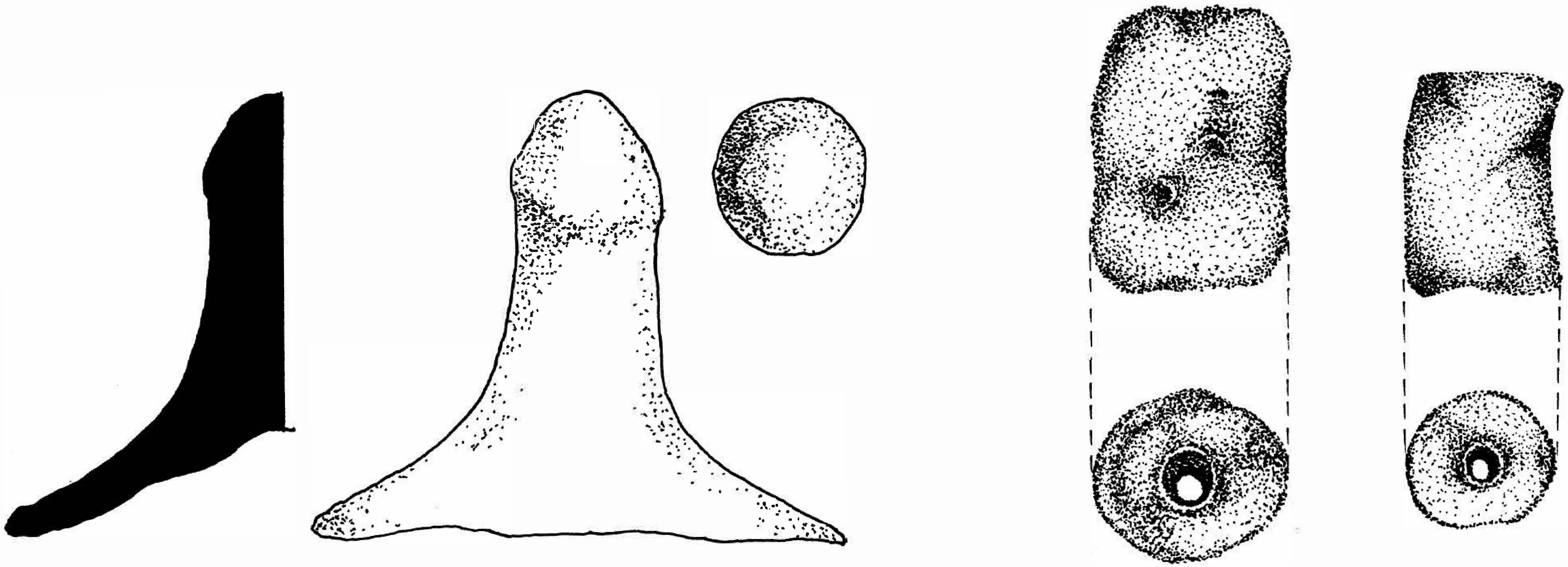


Plate 11. Phallic-shaped Pottery Knobs. Clay. All Recovered from Bongkisam, Trench II, Depth 6-12". Natural Size (Chapter III.16.c)a



(a) (b)

Plate 12. (a) Phallic-shaped Pot Knob. Clay. Sungei Ayer, Trench W/C, Depth 6-12". Natural Size (Chapter III.16.c).

(b) "Net Sinker." Clay. From Luzon, Philippines. After Tenezas, *A Report on the Archaeology of the Locsin-University of San Carlos Excavations in Pila, Laguna* (Chapter III.16.d).

PART IV

MINERALOGICAL EVIDENCE

"It was not until iron could be converted into well-hardened steel, that it was a better material than bronze for any use. Its long dominance owed more to the wide availability of its ores than to any overwhelming superiority of things made from it."

Cyril Stanley Smith, *Made of Iron* (Introduction), 1966.

". . . a heavy malleable ductile magnetic chiefly bivalent and trivalent silver-white metallic element that readily rusts in moist air."

Webster's *7th Collegiate Dictionary*, 1965.

A fortified tonic of high potency in Iron, Thiamine, Riboflavin, Niacinamide, and Vitamin C together with supplemental amounts of Calcium, Pantothenate, Pyridoxine, Vitamin B12, Inositol, Methionine, Choline, other B Complex Factors found in yeast.

Geritol Tablets (label), 1968.

IV.20. ORE SUPPLIES AND THE DELTA INDUSTRY

We have seen a lot of delta slag and associated crucible in the two preceding parts of this report. It is time now to go further afield, and look in particular at the source of the metal involved in these large if simple operations.

The geology of Borneo is still incompletely known, and (as earlier indicated) this is particularly so for Sarawak, where there were no government geologists until after World War II. Since then, vigorous work has been conducted by an exceptional group of men. But the emphasis on minerals has of necessity been towards "development" of those which rank as economic assets. Iron has not ranked anywhere near that category in this country during modern times. Kalimantan, just over the watershed from the Sarawak River headwaters, has a fuller tradition of geological research, as well as iron of "commercial" potential.

To pursue all the geological implications of iron distribution would exceed the scope and space available in this Data Paper. This and other laboratory detail awaits closer analysis at a later date. The chapters in this Part (IV.20-25) deal as briefly as possible with bare essentials of this sort which relate to delta iron-working problems directly, where *any* relevant data is available--it is usually still very inadequate.

First, of course, there is the question: where did the ore come from, to be heated and treated leaving slag as sad residue to tell the tale these centuries later? If one had to search for large-scale deposits of "good quality" ore, such as interest modern industrialists, the answer could only be: by sea, from a considerable distance. No such quality ore has been found close to the coast in southwest Borneo, although the terrain has been fairly well prospected in recent times, and effectively mined for gold, antimony (intermittently), and bauxite (since 1950).

But if iron was so brought from afar, the new question would have to be: why, then, work it in this out-of-the-way place--and one difficult of approach for sailing ships? The large supplies of mangrove for high-firing fuel, clay for crucibles, and intelligent inhabitants as cooperative labor could well influence a decision to carry ore and to work it here. But similar conditions operated elsewhere in the islands, especially in the southeast closer to possible bulk sources of ore. And ancient transport of any ordinary rock in bulk over these monsoonal seas stretches towards improbability.

Once the basic simplicity of the delta smelting process is accepted, there is no need to look so far afield. If low-grade ores were used without elaborate mining and carried in by local craft, down the big rivers from inland and through the delta laterally, then Jaong, Buah, and Bongkisam became logical centers for the whole business.

There is an abundance of low-quality iron ore all through this part of Borneo. The far inland people, with long and costly trade routes to the coast, contrived to extract iron from the surface of the ground into the twentieth century--we gave one example earlier and will presently see others. "Poor" surface ore is still plentiful behind the coast, though the Santubong operations before 1350 A.D. must have much reduced the more easily available supplies.

An iron ore may here be accepted as rock containing at least 20-25% of iron, normally as iron oxides. The easiest iron ore to work, especially by the "wootz" method discussed in the previous chapter, is magnetite, which has a high content of relatively easily extracted iron (over 60%). But this ore is rare in southwest Borneo (so far as is known), although there is a good deal over in the southeast where it has been used by the native peoples, mining with ropes and pulleys and wooden hammers.t[2]

The practicable ores which could have been available locally in quantity come down to threet limonite (iron content very variable but usually 25-58%), sphaerosiderite (25-40%), and haematite (40-65%) with the related martite recently re-located upriver (67.75% iron, which is very high).

Limonite ($2Fe_2O_3,3H_2O$) occurs widely on the surface in boulders and irregular deposits--another form is the "bog-iron" of swamps. It is usually brownish-yellow, and gives a rusty color ("red ocher") to many sandstones where present. The Sarawak form has a high porosity, which assists firing at low temperature, e.g., on an open hearth as proposed for the delta.t[3] There are also important limonite deposits on Karimata Island off the south coast, historically mined by the Chinese, some 250 miles round the coast from Santubong Bay.

Sphaerosiderite (iron *carbonate*) which occurs in river beds in interior Kalimantan, probably too far from the delta to be a practicable source, but of importance because its native treatment has been more fully described than any other for Borneo (by Schwaner; full text in Appendix B). This may be present in Sarawak also, on a workable scale, especially in river beds.[4]

Haematite (Fe_2O_3) occurs here mostly in red earthy lumps, very common behind the west coast. This is a valuable iron ore in modern terms if concentrated (as it is around Banjarmasin on the southeast Borneo coast), but in West Borneo it is very widely diffused in medium quantities. It is of special interest here, however, because there is abundant evidence that haematite was well understood and much used by Borneans before iron in the middle and late stone ages. Ground haematite occurs in archaeological deposits dated at least as early as 3000 B.C. in the Great Cave at Niah, especially in powdered form as a dense and brilliant dusting on human burials. The superb Painted Cave at Niah has 200 feet of lurid wall paintings, largely of ships executed in scarlet haematite, associated with T'ang and Sung Chinese stonewares (identical to those in the delta) which litter the cave floor along with glass beads (likewise identical). Haematite was also used to color the massive "three-color" ware pottery urns of the late stone age at Niah and on Burong Island in Brunei Bay. There is thus a long background to use of haematite in West Borneo.[5]

Martite, a high grade ore ideal for high-temperature blast furnaces (and thus of more interest to present-day geologists), but probably difficult to work by simpler, delta-type methods (see analysis in next chapter, IV.21, second table). The challenges of such rewarding ore might cause new, improvised or improved methods developed from an established local technology?

More broadly, very widespread are occurrences of concretions and nodules of ferrous oxides, often in hard clay lumps found in erosion and alluvial deposits, including in association with gold-bearing strata. These can loosely be termed *laterites*. Such occur plentifully around Bau, further north on the Rejang and Baram. They require extensive accumulation to be at all "workable," but that could have been less of a problem in earlier times with high demand.[6]

Thus, by and large, there are several ores suitable for different levels of working, with supplies in the Sarawak River watershed and areas accessible by boat thereto--without open sea journeys of more than a few miles--adequate to support the sort and scale of industry indicated by slag and crucible remains at Jaong, Buah, Bongkisam, and elsewhere. If sea-going carriage is allowed, very large deposits of high quality ore, including magnetite, would be available from along the south coast of Kalimantan past Tanjong Datu (see further at IV.24).

Most of these ores would benefit from preparatory roasting and treatment by fragmentation, such as is reported in some of the ethnological accounts. But over-fragmentation can be counter-productive, as very small pieces need a greater draught of air. Most roasting can be done in the open, as there is normally no need to keep out excess air. The oret can be spread on a lattice of raw wood. There is no present indication of roasting down in the delta, and it is likely that where this was necessary it would be undertaken *before* the ore was brought down to the main working sites for actual smelting or further refinement.[7]

It is also likely that haematite played a significant part in the transition from stone to iron age technologies in Borneo, as one of several such links of continuity (cf. stone tools, gold and diamond mining, etc., in Part V).t[8]

IV.21. ORE ANALYSES

It has proved difficult to interest metallurgists in studying the delta slag or related ores which seem to have little economic or geological interest today. Perhaps the publication of this paper will stimulate a fresh approach; producing further results with which we can elaborate in the future. There are several ways of analyzing ore and slag, and it is not always easy to compare one analysis with another. The available delta data will be presented as simply as possible, both as relevant to the iron-working process and hopefully as information for comparison with other studies to come. Thanks are due to the Furu-Kawa Mining Company of Japan, who did the Bau ore analyses below, results reported 3.8.62; and to Dr. J. H. Hillebrand of A. Soriano Y Cia of Manila, the largest Philippine mining concern, who kindly took a lot of trouble to help with the recalcitrant slag; results reported 12.12.61. There are no laboratory facilities for this kind of study in Borneo, as yet.

(a) Bau Ores

Two samples of surface iron ores from Bau, gold and antimony mining center from 1840 until modern times, in the upper reaches of the Sarawak River, were tested with the following results:

Assay Tests on Bau Ore (2 samples)

Mineral	Bau/At(%)	Bau/B (%)
Iron oxides	66.97	66.54
Aluminum	0.13	0.14
Potassium	0.019	0.055
Sulphur	0.236	0.017
Zinc	0.03	<0.01
Copper	0.117	<0.01
Manganese	0.11	<0.01
Arsenic	<0.01	<0.01
Antimony	0.02	0.02
Nickel	<0.01	<0.01
Titanium (as TiO_2)	<0.01	0.17
Silica (as SiO_2)	1.21	3.48
Combined water	2.20	0.73
CaO (lime)	--	--

These ores, readily available by river boat to Santubong, are typical of the medium-grade surface ferrous deposits found throughout the area. Too scattered and low in iron content plus concentration for ordinary industrial extraction, they are perfectly practicable for what might be described--with respect rather than with any derogatory inference--as a "peasant industry" of prehistory.

Tylecote has defined "the best indication of a good ore is ore low in silica, alumina, lime and magnesia" (182). Bau ore is low in the first two and without the second two. The main assay was done in Japan and leaves some details unclear. For a second set of figures we have been able to elaborate by correspondence, with useful results.

(b) Subang Ores

The Bau ores have not attracted any modern interest. But during the period of this delta study, others of exceptional quality have been identified well within accessible range of Santubong, about twenty-five miles from Bau. These have more silica, alumina, lime, and magnesia than the Bau examples, but are also very high in ferrous oxides--higher, for example, than any of the twenty-three listed for early Britain by Tylecote (180-181).

This martite-type ore was "discovered" inland in the First Division, in Land Dayak country near the headwaters of the Samarahan--the river system running east of and in rough parallel to the Sarawak River--in 1962.[1] Outcrops of this ore cover an area of several miles, including Sungei Limo, Sungei Batu Besi (i.e., "River of the Iron Stone"), Sungei Batu Puteh ("River of the White Stone"), and a 3 ft. x 8 ft. vein of ore and related garnet in Sungei Dawan Kenau. Dr. A. Pimm estimated a *surface* 1,000 tons; it is not known if the underlying deposits are of the same quality as those tested. Tests cover a wide range of the surface ore deposit, and were reported on by the Mineral Resources Division of Overseas Geological Survey in Special Reports 103 of April, 1963, and 122 of November, 1963, which have kindly been made available for present purposes. The area of the deposit is hereafter called Subang.

In general, the Subang ore has proved to be of: "very high grade . . . . containing only very minor amounts of quartz and silicates, and low contents of phosphorous and sulphur" (103: 2).

Two Subang ore samples from Sungei Limo are of special interest here, as this place also has some iron *slag* on the spot (IV.22 below)t Two Limo ore samples give:

Subang (Limo) Ore Analyses

	S.11477	S.11478
Iron Oxides (Fe_2O_3)	94.44%	81.90%
(FeO)	2.17	13.45
Silica (SiO_2)	1.40	1.79
Aluminum (Al_2O_3)	0.38	0.93
Lime (CaO)	0.12	0.13
Magnesium (MgO)	0.17	0.22
Manganese (MnO)	0.14	0.16
Titanium (TiO_2)	0.05	0.07
Sodium (Na_2O)	0.18	0.15
Potassium (K_2O)	0.10	0.10
Phosphorous (P_2O_5)	0.06	0.06
Sulphur (S)	0.002	0.01
Water	1.19	1.54
Total *iron as Fe*	67.75%	67.75%

One notices the *absence* at Subang of zinc, copper, arsenic, antimony, reported in the Bau ores; thetpresence of lead and magnesium at Subang (also in all other samples there) which does not occur in the material examined previously nor in the Philippine slag (IV.23). But zinc, copper, arsenic, antimony all occur in streams drawing *from* the Subang ore area (S.11419, etc.). As ever, comparative methodology is in part involved, but the O.G.S. analyses are very exact, as required in assessing "a possible economic asset to Sarawak's future"--which remains untouched at the time of this writing. That is untouched by the elaborate demands of modern industrializationt

Such ores were available to and must have been apparent to the Dayak peoples living all around Subang and Bau and the whole hinterland of hill countryt Their direct, effective but simple mining methods would have left no trace normally recoverable these centuries later. And this is one of the parts of Borneo in which active ore collecting--for iron, as for gold and diamonds--is most fully recorded in historical times, too.t[2]

IV.22. SLAG ANALYSES AND SOME COMPARISONS

Slag analysis was concentrated on the richest and deept est of the delta iron sites, Buah, as the opportunity for laboratory work was limited. A special series of slag samples were taken from trench DA/17 (5' x 5') at the center of each alternative 12" layer: DA/7 on the edge of the more intense slag concentration. It gave a total slag yield of 13.8 lbs. per surface square foot. This was felt to be a reasonably "typical" context for slag in the delta as a whole.

The four samples were all given spectrographic analysis. In addition, a duplicated sample from 48-60" was measured by assay for comparison.

(a) Assay Analyses

Assay results depend, like most such tests, to an appreciable extent on exact method at the laboratory. And without a long series of measurements, a few reports are difficult to assess as regards degree of variation, since no standard or range of differences are established. The 1961 assay for Buah was made more attractive, however, because one of the rather few clear pieces of information in Everett's 1909 publication on Santubong was an assay made by a Mr. C. J. Brooks (not further identified) for some slag from Santubong. The following table summarizes the two sets of figurest

Delta Slag Analyses

Mineral	Buah, 1961 D/A 17, 48-60" % content	"Santubong," 1909 (no locality) % content
Ferrous oxide ("iron")	57.13	65.5
Silica	31.43	22.4
Aluminum	8.05	7.6
Calcium ("lime")	0.42	2.3
Manganese	0.40	---
	0.17	---
Copper	0.01	---
Titanium	0.01	---
H_2O, etc.	2.4	2.2

The 1961 assay is, not surprisingly, more refined. That the four rarer minerals totaling one-half per cent are not represented in the earlier form cannot be taken as significant. It should be noted that all of these are present in small quantities in the ore assays from upriver Bau, already cited. All the items making up over 0.5% are present in both assays.

All things considered, the differences between the two are not large, though the ferrous oxide residue in the earlier assay seems rather high. These differences are less than those between iron ores upriver at Bau and Subang. After discussion with mineralogist friends, it does not seem desirable to draw any further conclusions without more knowledge for the whole area. As it stands, both slag results plausibly represent a rather crudely smelted ore, consistent with derivation from the types available in the vicinity, though not carrying any final proof that this necessarily is the source. Here a small note should be made (for future study) of the absence of some upriver Bau ore constituents in either of the slags. However, in another slag sample from a non-archaeological context an Lundu, inland and 20 miles west of Santubong, but easily accessible by water, tested in 1961, *all* the Bau ore constituents were present: 40.08% iron oxides, 23% aluminum, 28.7% silica, 0.74% manganese, 0.4% potassium, 0.28% titanium, and so on.

(b) Spectrographic Comparisons

The spectrographic method gives somewhat different levels of result from assay and other chemical quantitative methods generally. It is sensitive to the presence of every component but initially reports on a broader spectrum. In the following table the four spectrographic analyses at Sungei Buah, DA/17, are stated in the terms of this Soriano analysis:

S -- above 1% of whole
M -- 0.1% to 1.0%
W -- 0.01% to 0.1%
Tr -- 0.001% to 0.01% ("trace")

The degree of variation here shown indicates some of the marginally firm conclusions on such essentially crude data, subject as it is to variable minor influences in situ over centuries. The figures at the foot of the table are for slag dry weight calculated per 100 cubic feet for each specified layer, to show variation in slag quantity by depth also (the overall DA/17 figure of 13.8 lbs. per surface foot refers to all layers in aggregate).

Spectrographic Tests from Buah (D/A 17, slag)

Mineral	Depth (inches)			
	0 - 12	24 - 36	48 - 60	60 - 72
Iron	S	S	S	S
Manganese	S	S	S	S
Silica	S	S	S	S
Aluminum	M	M	W	W
Copper	M	W	W	S
Titanium	W	W	Tr	Tr
Slag weight per 100 cubic feet	254	240	206	290

The higher figure for copper, deep at 60-72", is the only significant "inconsistency" in the spectrographic series and could be due to some other undetected material in the sample. The spectrographic method agreed with assay in failing to find any trace of arsenic, antimony, zinc, nickel, etc., all present in the Bau ores. Any persistent identification of titanium, copper, and manganese could eventually help to distinguish or relate delta slag from the otherst

(c) Subang Slag

Some slag found in the open at Sungei Limo, near Subang in the upper Samarahan has been noted in the previous chapter. This probably represents the upriver carry-on of localized smeltting in southwest Borneo, and cannot be dated at present. A sample of the Sungei Limo slag was given X-ray fluorescence analysis, by the Overseas Geological Survey, London, which revealed traces of zirconium and (unusual for Borneo) silver. Their report carefully points out:

> . . . a typical fayalite slag such as is found in primitivetiron smelting districts throughout the world. A qualitative X-ray fluorescence analysis indicated trace amounts of copper, zirconium, titanium and possibly of silver. These elements may derive from both the iron ore (primary, or soil concretions) and from the sand or other silicaceous flux added in order to produce a fluid slag, but siderophile elements (especially gold) from these sources may be present only in greatly reduced proportions in the slag, being concentrated mainly in the metallic iron of which we have no sample. Without

> data on the trace elements in the local soil concretions, and preferably also in the metallic iron, one cannot hope to prove what type of ore was smelted. It seems not unlikely that soil concretions from the Subang area would show a rather similar trace element assemblage to that of the weathered magnetite ores, and yield rather similar slags. Many primitive iron smelters have wisely preferred porous secondary iron ores to dense magnetite ores which take much longer to reduce, but on the present evidence no decision can be reached as to the ore smelted at Sungei Limo.[2]

This upriver slag, like the one from Lundu up another river across Santubong bay, again shows the extent and variety of activity and of mineral sources or styles in use over southwest Borneo. It may well be that the upriver slag in part represent post-delta operations, after the eclipse of the downriver industry when iron-workingt"took to the hills" (cf. VI.37). In any and every case, the diversity of the data continues to make it all persistently interesting as well as potentially important to learn more.

(d) What These Slag Analyses Show

> The archaeologist must be careful in dating iron smelting sites by the type of slag producedt He cannot regard a medium-iron low lime slag as automatically a produce of the bloomery if it is in a late medieval context. The slags containing over 40% iron (55% FeO) and less than 80% lime are undoubtedly bloomery slags. . . . Since reliable historical evidence is totally lacking, this is one of the points that wants confirmation by excavation. . . .

Thus Dr. Tylecote (305) writing for the British Isles, where so much high-quality research on the iron age has been carried forward. On this definition, Buah has a bloomery slag, consistent with all other indications of smelting in an open hearth, bowl-type furnace (II.10, etc.).

Although comparisons with Europe can be very misleading, it is of interest here to glance at bloomery slags studied with special care by Dr. E. Straker from prehistoric Roman sites in the Weald of Kent (cf. Coghlan: 42). The delta slag is well inside the range of these English (Kent) ones except that it is notably low in lime. Such variations are commonplace and the degree of "waste" in iron-bearing material at Buah is not high by some other standards.

Borneo and British Slag Compared
(4 main constituents, as percentage of whole)

	Sarawak: Buah DA/17	England: Guestling, Kent	Other Kent slags (range of variation)
Iron oxide	57.1%	53.4%	31-59%
Silica	31.4	32.4	29-38
Alumina	8.0	7.1	2-7
Lime	0.4	3.2	2-8

The following table, derived in part from Coghlan and Tylecote, indicates this pattern in very crude terms:

Ferrous Oxides Remaining in Ten Selected Iron Slags
(in increasing order of superficial "efficiency")

Code	Country	Site	Period	Percent iron oxides remaining
1.	England	Blewburton Hill, Bertes	Pre-Roman or Roman	81.2%
2.	England	Maiden Castle, Dorset	25-45 A.D.	75.8
3.	Philippines	Calatagan, Luzon	See IV.23	72.1
4.	England	Kestor, Devon	?3rd C. B.C.	65.7
5.	*Sarawak*	*"Santubong"*	*See above*	*65.5*
6.	England	Wilderspool I Lancs (cf. 10)	Roman	58.53
7.	*Sarawak*	*Buah, Santubong*	*"Sung-Yuan"*[3]	57.1
8.	England	Guestling, Kent	Roman	53.4
9.	*Sarawak*	*Lundu, First Division*	*Not excavated or dated*	40.1
10.	England	Wilderspool II, Lancs (cf. 6)	Roman	22.0

The differences between nos. 6 and 10 from the one place, Wilderspool, well illustrate what Coghlan (44) emphasizes as "the widely varying properties which may be found in slags even when found in the same site." Bearing this and the meager Southeast Asian data in mind, it can be safely concluded that delta smelting was, of its kind, complete enough in this respect.

IV.23. A PHILIPPINE SLAG COMPARISON

One of the underlying themes of this paper is that iron slag in all its unlovely associations must be taken seriously by archaeologists in Far Asia; and, by tropic insinuation, that the tendency has rather been to overlook or underemphasize the stuff since it indeed is heavy and so tedious! Through the courtesy of Dr. Robert Fox, T.H. was allowed to take for testing a sample of slag from the famed Calatagan excavations in Luzon, Philippines, a large set of burial sites in time more or less starting where Santubong leaves off. Little has been said about this slag in the Calatagan reports.[1] Slag is also strikingly present in the Laguna excavations, near Manila, 1967-8, including what appears to be a kiln; the Laguna site approximates in time to delta's Bongkisam (cf. earlier comment in III.16). No descriptions or analyses of slag or its relationships have yet been published for these or other important sites so brilliantly researched in the Philippines.

The Calatagan slag was assayed by Soriano again through Dr. Hillebrand, as with the Buah deep sample already discussed. Regults from the two compared:

Philippines and Borneo: Assay Results for Slag

Mineral	Philippines Calatagan	Borneo Buah DA/17
Iron oxides	72.10	57.13
Aluminum oxides	6.12	8.05
Calcium oxides	1.29	0.42
Manganese	0.11	0.40
Silicates	20.38	31.43 (+)[2]

The Calatagan slag broadly resembles that from the Sarawak River delta. Dr. Hillebrand considers the difference to lie within the range of variation as between samples of different levels from the same place or under slightly different conditions within one area.

There is nothing here indeed to contradict even such an otherwise seemingly wild suggestion as that slag pieces picked up in southern Luzon could have come from the same ore-source and method as those at Buah. Or that both sorts of slag originate in one sort of ore source--one of the common, widespread ores. The higher degree in Luzon of remaining iron oxides would suggest the smelting of the Philippines slag as possibly more "primitive" than that in West Borneo, although later in time? But we have seen how much this can vary from slag to slag, and must await further Philippine analyses.

Whatever the doubts, the inescapable inference is of iron smelting at both ends of a long arc of ancient contact, though at Calatagan associated with *later* Chinese ceramics and other evidence. Possibly, in the Ming, these operations moved from Borneo up there? *Prior* to the result of the Calatagan analysis, upon seeing the slag brought thence to Manila, on the basis of his previous visit to Sarawak and on-the-spot examinations at Santubong, Dr. Hillebrand wrote:

> We will run complete analyses on the Buah 48-60" and the Calatagan slag. I will forward them when ready. [These are the figures published above.]
>
> I would point out that should the two be similar--and I suspect they will be--and we therefore assume they are the products of identical process, gold smelting would seem to be ruled out. There is no logical source for delivery of gold ore to Calatagan.[3]
>
> If from iron smelting, the slags may represent either initial smelting from ores or secondary smelting of impure pig iron. The material would represent the dross which was not chemically reducible by their crude smelting practice and the high iron content is not unexpected. If original smelting, the locale represents either the source of ore--probably lateritic--or source of fuel. If secondary smelting the locale or finished articles *(or perhaps high grade pig iron for export to China?)*.

So much, then, for the metallurgic indications which by their nature tend to limit or negate certain ideas rather than provide positive meaningful answers.

Summarizing, we have:

(i) Abundant iron slag in southwest Borneo contains a fairly high ferrous residue.

(ii) The content of this slag is close to that from over 1,000 miles away in another prehistoric site in the Philippines containing both indications of iron-working and quantities of Chinese stonewares and glass beads.[4]

(iii) Several sources of ore indicated, including surface local, but *possibly* also further afield.[5][a]

IV.24. SOME ISLAND LOGISTIC PROBLEMS

The delta method of working iron ore was decidedly "wasteful" at the level of modern technology, yet well within the effective limits of its timet There are indications that the rather fully organized back-yard furnace system common in ancient China and resuscitated as a Communist drive recently is, for instance, no more effective. Experiments by a group of Danish archaeologists who reconstructed an early European smelting furnace gave a maximum "20 per cent efficiency, and that took a lot of work" (*New York Times*, 4 Dec. 67). The wastage at Santubong was high; but certainly not too high for the place, time, and space there, then.

(a) "Wasteful" Process, "Poor" Ore?

In considering this prehistoric iron industry, it is necessary to think in Asian and specifically in Borneo terms of a millenium or so ago, rather than in the mood of today's industrial technocracy. Today's producers are in fact beginning to return to an interest in the lowtgrade ores we have earlier discussed and which lie scattered all over the Southeast Asian landscape, long regarded as substandard, "unproductive" in the historic view. The Japanese have begun exploitation of somewhat similar ore material occurring in bulk in West Malaysia. For this to be economic, now, it requires massive, intensive, mechanized mining, under formidable cost (labor, power, communications, tax) conditions. After the Stone Age, somewhat similar considerations must have applied in places like Sarawak in East Malaysia--and indeed throughout the islands as on the mainland too. Iron became the most important single item in the expansion of human achievement; above all, in making possible a reasonably productive settled agriculture on poor soils covered with rain forest jungle, as in most of Borneo. The use of iron and the skills with it spread unevenly and sometimes surprisingly slowly--into much of interior New Guinea not until after 1940. At the same times, in many of the richer land areas, population expansion and multiple new needs raised the demand for iron, especially in places where it was naturally scarce or by usage became so. Under these conditions, it grew economic to travel afar in search of iron, however "low" the ore grade and "wasteful" the process, provided the poorer stuff was accessible (either on the coast or brought down by river) and the facilities to work it "cheaply" were available in bulk.

The Sarawak River delta was drawn into this web some time after 700 A.D.--which is not, of course, to suggest that iron tools were not in use in southwest Borneo before them; nor that Jaong is the earliest organized iron smelting site in this part of the world. Others maythave risen and fallen, as Jaong did, before and even quite close by, unremembered and as yet undetected.

To carry low grade ores away overseas from Borneo in those days of sail was impracticable. To work it on the spot vastly reduced the problems, even if it involved inconvenience and discomfort for any outsiders concerned--if, indeed, there were any? Where the sea carriage of the smelted product could be done by "locals,t" using smaller boats to bring the iron into trade entrepôts, other problems were soothed if not actually solved. That is where the sea-going traditions of the South China Seats "Bajau,t" "Bugis,t" and other peoples of the Borneo coast can have helped so much; there was no real *need* for any prime buyer of the end product to come to Santubong from India or Malaya, Brunei, Sabah or the Gulf of Siamt The whole business could be conducted through agents: from (roasted) ore out of the hinterlandt behind the coast down to the smelters in the delta, then on overseas or back along the coast (or even back inland)t As archaeologists, we are presently bound to think in these terms. There is no satisfactory evidence that any significant number of "Chinese" or "Indians" or any other identifiable non-Borneans participated personally and regularly in the delta operations. Evidence of trade and intellectual contact with such outsiders is overwhelmingly abundant. But nothing on the present record says this had to be *direct*, while a good deal suggests it was not so (for instance, the absence of ordinary, everyday artifacts of non-Bornean origin)t

(b) Demand and Distance

To carry low-grade *ores* away from Borneo by sea, by sail, would clearly raise serious logistic problems. There is no firm evidence of any such traffic through the islands in the records and annals known to us, from Arab, Indian, or Chinese sourcest But Professor Paul Wheatley, in his study of the Sung Maritime Trade, has drawn attention to references in Chinese texts of the delta period to a mineral *wi-mung i* which is listed among exports from Asia Minor to China, and, as he mentions:

> *Sung Shih*, chap. 490, also notes that *wi-mung i* was brought to China by Arab merchants. (Wheatley, 1959: 74)[1]

The identity of *wi-mung i* has been the subject of some disagreement--not surprisingly, since little enough attention has been paid to base metals as compared with seemingly more precious or spicey or jeweled things. Dr. Wheatley decides in favor of the view (first put forward in 1876 and later rejected in favor of cobalt) that *wi-mung i* is:

> the hydrated iron oxide known as limonite.[2]

Limonite is one of the commonest low-grade iron ores of southwest Borneo and widely. This reference therefore deserves further study in the texts. It *could* be that the "Arab" traders were collecting ore *on the way* to China, in which case it might make an economic extra-load. There is certainly an abundant literature of Arabs and others carrying *iron* from India and elsewhere long before Jaong (cf. Forbes: 443-446).

Wheatley does not return to the matter in his later discussion of iron (p. 117), which, however, he regards as "among the commonest" things "shipped *from* China *to* the South Seas." He goes on to say that as there are only a few textual references to it "we may safely regard this account as incomplete." The general view has long been that at first iron came to Southeast Asia *from* China, or somewhere else; and this is deep-seated in scholarship. The idea of iron being brought *to* China from such "primitive" lands as Borneo may seem strange on this frame of thought. Wheatley himself continues with iron by saying:

> Chao also included iron among the products of Tong-King, *whence it must have been a re-export*.[3]

The assumption behind the phrase italicized (by us) above appears to be negated by the evidence for T'ang-Sung delta iron smelting much further afield than Tonkin or Indo-China. For it is most improbable that the delta smelting from Jaong to Bongkisam represents an industry *purely for local use*. The materials required are so widespread in West Borneo, there would be no point in bringing the ore and the people down to the delta on that scale in order to bring *all* the resulting metal back inland. Nor is it believable that this to-and-fro might be necessary because the "primitive" inlanders did not know how to do it. The processes could be simply learned. There is incontrovertible evidence that they were fully, even finely, so learned, as far inland as the remote interior of the world's third largest island long before the first European contacts (more on this at VI.). Moreover, there is slag at many places in the Sarawak River headwaters and throughout the hinterland, representing other, if smaller-scale, on-the-spot iron-working (cf. the Subang and Lundu slag in IV.22 above).

There is also significant evidence that in China itself iron was at relevant times in short supplyt See especially Dr. Robert Hartwell's detailed work (1962) for the period 960-1126 A.D. In another and later paper Professor Hartwell has summed up a background which overspilled across the South China Seat

> From about 750 to 1100, China experiences a series of economic changes roughly comparable to the subsequent patterns of European growth from the Crusades to the eve of the French Revolutiont The spread in the use of money, development of new credit and fiscal institutions, increase in interregional and international trade and colonization of hitherto marginal land which took place in the Occident during the half millenium preceding the Reformation was paralleled by an earlier era of progress in East Asia during the two-hundred-fifty years from the rebellion of An Lu-Shan (755) to the treaty of Shan-yüan (1004)t And the achievements of late sixteenth and early seventeenth century England, which John Nef terms an "early industrial revolution", were in many respects even exceeded by the impressive expansion of mining and manufacturing in eleventh century China. (R. Hartwell, 1966: 29)[4]

There is much else on the fresh approach of Hartwell and his colleagues in the Department of Chinese Social and Economic Thought and History at the University of Chicago which opens up vistas towards new ideas with relevance for Borneo too, but which cannot be properly pursued in this placet In the paper above cited, special stress is laid on massive deforestation in large parts of China from the late Tang on (and locally earlier) as a direct result of smelting operations (cf. III.18 further).

(c) A Suggested Sequence for Delta Ore-Slag-Iron Relationships

To get the delta industry into some sort of perspective, a simplified logistic sequence is here proposed as a basis for further study in the future.

(i) The systematic extraction and use of iron, beginning in India about 1000 B.C. and in China a little later, spread fast over the mainland, greatly influencing major centers of agriculture, population, etc. (cf. VI.34).

(ii) As techniques, demands increased, workable ores became less easy to obtain, while at the same time increasing populations with new crops needed to open up new land (e.g., to fell the rain forest for rice); high-temperature fuels like charcoal also became important (and locally hard to find in bulk).

(iii) Alternative sources for ores (and fuels) were sought; if not available on the spot, then overseas. One such source was found at Santubong sometime after *ca.* 700 A.D., and strongly by *ca.* 1000 A.D.--perhaps only one of many, others as yet unrecognized.

(iv) Here local ores were treated, both smelted to wrought iron and/or refined to steel; and then in part carried (probably by maritime middlemen) to demand centers--either elsewhere on the island or overseas.

(v) The techniques used at all stages, from ore extraction to shipping, combined outside know-how and endemic intelligence.

(vi) This basic pattern (i - v) by no means excluded a big range of variants (cf. Appendix B).

(vii) For example, as more and more ore was treated in the delta, with deep and local know-how established there (over centuries), the easiest local ore was diminished and the incentive thus arose to bring in ore from further and further away, up to a "point of no return" for effort.

(viii) If any very *good* or special ore was found (e.g., martite at Subang?), it *might* have been worth taking it direct to a large demand-market elsewhere for working there. This could happen side by side with refining other ores locally.

(ix) Similarly, side by side with the production of metal (steel?) bars or other raw "pig" forms for export, some of the iron was no doubt traded locally as well. Not all had to be refined, either--and with the good ores, this may have been unnecessary.

(x) Equally, some making of actual tools for local use went on in the delta after the smelting and/or alongside it--though the present evidence indicates that this was not a major activity comparable in scale to the smelting (cf. V.26).

(xi) Some locally made objects, relying on innate native skills (especially fine steel), may well have been exported as far afield as places like China (in return for their wares), with sophisticated merchants whose customers loved all sorts of exotica--e.g., the beautiful *parang* swords for which Sarawak is still known, and which almost certainly date back to this period and the "damascene" cult which then developed.

(xii) China's own concentration on and specialization of advanced cast iron techniques in itself created a demand for the input of more malleable iron forms to temper the basic produce for many other purposes. Imported ingots of this *steel* met a local need in Chinese markets of Sung times. In this connection, our friend Cheng Te-k'un has lately written:

> It seems common sense to presume that the *cast iron of Santubong which was smelted* on such a large scale could only be exported by sea-going fleets which arrived from the north.

Although we fully share Dr. Cheng's concern with common sense as a first-line weapon in interpreting the past, the evidence of previous chapters--not yet analyzed when he prepared his excellent text--does not confirm the passage regarding cast iron as italicized (by us). The probability of direct sea-going traffic with China is by no means to be discounted, however, and is in itself not at all incompatible with a smaller scale maritime trade at the same time (see xvi - xviii below).

(xiii) In addition, Chinese love of damascene blades led not only to new innovations at home; but also to

> . . . the importation of the hyper-eutectoid wootz steel of India in relatively small amounts, from about the +6th Century onwards. This trade seems to have taken several routes; e.g. Persia and Kashmir *as well as Malaya and Indonesiae* (Needham: 48)[5]

(xiv) A good deal points up the probability that not only was this wootz-type steel being brought from India to China *via* Malaya-Indonesia, but that Santubong was a way-station and subcontractor in this trade, an important one, using methods in part developed out of a westerly ("Indian") wootz technique?

(xv) There is obviously no reason why the same boats that brought Chinese stonewares and took away delta steel (whether directly or indirectly) could not equally have brought in other things made of iron lying outside local skills. This must surely have applied to *cast iron* forms, such as big cooking pots and tripods for use over fires, which remained a Chinese world monopoly into the fourteenth century A.D.; China is still today the source of all this supply for local use in Borneo. (Most of the Chinese early textual export references probably refer to cast iron; this has perhaps caused some of the misunderstanding about a more general export of iron-steel from China; see further in VI.34.)

(xvi) But the most "obvious" trade would be to ship pigs of steel from Santubong towards China, by whatever intermediaries, in exchange for the stonewares of which a big portion litter the delta sites and untold numbers penetrated Borneo even unto the furthest uplands.

(xvii) This "barter" makes sense of the great quantity of ceramic import artifacts found almost everywhere in Borneo where cave and other burial and open sites have as yet been explored, as well as the very many Chinese vessels surviving in the long-houses of the upland Kelabits or in the backrooms of the downriver Melenaus--of which a broad but fine, fair sample of some thousands have been collected for the Sarawak Museum since 1947.

(xviii) It can easily have been the case, then, that some vessels came direct from China to anchor in the delta mouth--especially after the compass simplified direct open sea travel (in the twelfth century), in addition to other and less direct operations by maritime agents.

(d) Other Transportable Ores of the Area

Those eighteen points give the best idea presently available of where Sarawak stood in this prehistoric traffic. Urgently needed next are insights from adjacent islands and the mainland. In the future, one would also especially hope for fresh insights from *southeast* Borneo. There are very large iron deposits, of all grades, in the Banjermasin area of Kalimantan, and notably on Subuku island off that coast. These, with lesser iron deposits in Celebes and Sumatra, give Indonesia a total of some 800 million tons of known iron ore, as calculated in the basic study by F. R. Tegengren (1923: 431).[6] This compares with about 950 million tons for all of China. As he points out, there is an abundance of ores in the whole Far East, notably again in the Philippines (200 million), though only "moderate" in Thailand and Indo-China. Tegengren estimated that even at modern use and population rates most of China had enough iron of its own for the next two centuries. Borneo, on this standard, has a seemingly unlimited excess. Moreover, all the mineralogical evidence goes to show that a great part of iron and other metal ores had been thoroughly explored long, long ago; indeed, that ancient knowledge was often more complete than modern knowledge in this field, especially as regards surface deposits.[7]

There certainly were metal shortages at one time and another, notably in parts of China in the Sung. But the Sarawak steel met a "luxury" need in any case and did not depend on basic shortages of iron cast inside China. The Sarawak River delta may have indirectly benefited from such uncertainties. But in a more local sense, there was not only abundant iron ashore, but huge amounts round the corner on Subuku and the main island, in manageable reach.

One of the few early *historical* references (pre-1800) to Borneo iron is an account of 1703 A.D.:

> Crimata, a small town situated to the southerly end of the Island of Borneo, sends to Bantam [near Java] a great deal of iron. (Ling Roth, 1896, II: 234)[8]

It should be emphasized that once *any* island people had learned how to locate iron and extract it, there was little point in bringing the metal in from elsewhere *except* in special forms beyond the capacity of simple local methods. It was more economic to make most tools on the spot, if ore was near. Nearly everywhere in the islands, ore is near. Then only large coastal communities, with easy ship supply, need rely on raw iron from outside. This was the position, for most of Borneo, until into this century. And though with improved communications native *smelting* is probably finished now, many islanders still trade bar-iron from the riverine bazaars and take it home to the hills to forge for their own tools of choice by their own traditional means (VI.36-37).

IV.25. THE QUESTION OF FLUX

One fairly small but important point of metallurgy remains. The Bau and other local ores, like every iron ore, contain gangue--non-valuable, non-metalliferous minerals which may offend both the purity of the end product and the process of smelting it efficiently. With some ores and processes, this gangue separates quite readily under heat, the valued portion liquifying to separate, more or less, from the unwanted remainder. With most, the first smelted product consists of the pasty mass of iron and a spongy bloom intermixed from the hearth (bown-furnace); the latter has to be extensively hammered to separate the slag. As R. J. Forbes says: "This is a tedious process which requires frequent re-heating of the bloom and much of the ore is wasted in the slag" (396).

Tedious processes, which meant little to the Dayak metallurgist, have little place in contemporary technology, unless they are physically minimal, if not actually passive. *Flux* is one regular modern answer to such difficulties. A flux is material added in the smelting process to influence the temperature and render it more easily freed of the undesirable ore minerals on heating, thus easing a satisfactory slag formation. Lime is one of the commonest and easiest fluxes. But the matching of the flux to the ore can be a definite problem--if imperfectly executed fluxing does more harm than good.

R. F. Tylecote pointed out that a good deal of archaeological literature goes astray on the subject of flux; and that whole pieces of limestone identified in prehistoric sites (in Europe) could not be so used, while even if ground fine it would "only reduce the melting point by about 50°C. which would not be of much benefit"; large quantities would actually be detrimental (Coghlan: 41, also casts some doubt on such findings for lime).

Lime would be the obvious flux in the delta, since it is a main constituent of the upriver terrain, as well as being involved as an early gold source (in the Bau limestone; cf. V.29). We have not succeeded in identifying lime in any form in the excavations, but negative evidence of this kind is not worth much. As metallurgist writers regularly emphasize, "the easier type of ore" does not require a flux (cf. Forbes: 396). It is this which put a premium on working the easier ores like haematite or limonite in the past.

The consensus now is that most early iron industries did not use a flux. They got around that difficulty either by using an easier, even if low-grade, ore, or by extensive roasting and other pre-treatment, or by much hard work with a hammer, or all of these. But there are a few exceptions, and in view of the intensity of the Santubong effort we cannot altogether exclude the possibility of this "advanced" technique here. The total absence of lime in the Bau ore is noted (IV.21, table), and this *could* make it significant that there is 0.42% calcium in the Buah slag analysis, and no less than 2.3% in Everett's earlier one probably from Bongkisam (IV.22, table). Everett's analyst, influenced no doubt by later day ideas, concluded:

> . . . that the process of extraction was rather crude and that limestone was not used therein.[1]

But this is open to a reverse interpretation also.

To the flux point here is Tylecote's discussion of manganese oxide, which should be considered together with iron oxides in judging the ore. Where manganese is present, as in some limonites, "it will appear in the slag, making more of the iron in the ore available for reduction to metallic iron" (182). It is worth keeping an analytical ear open for manganese in further studies for the area, noting meanwhile its presence in the Bau ore as well as in the Buah and Philippine slags.

The same applies to sulphur, which Tylecote summarizes as "a very detrimental element in iron" (191). Most iron ores are very low in sulphur, which is usually introduced fortuitously in the fuels used, especially coal, which is known to have raised the sulphur content to 0.485% in a cast iron example from Roman England. We have already noted that one of the Bau ores analyzed has 0.236% sulphur though the Sabang ores carry much smaller amounts. The Buah *slag* has 0.17% sulphur persistent, however (IV.22). This again suggests that a Bau-type ore was used--and incidentally perhaps the skill in this at the delta level of smelting: the works were not upset by a sulphurous ore?[2]

CHAPTER NOTES

Part I. Introductory

Chapter 1. Delta Background

1. T. Harrisson in *S.M.J.*, 12, 1964: 341-511, part of a full text in book form to be published by Macmillan, London, during 1969 under the title *The Malays of South-west Sarawak before Malaysia: a Socio-Ecological Study*. This work is centered on Santubong and the delta generally, in terms of modern living, and may provide some useful background to the present prehistoric survey.

2. Everett died in the nineteen twenties, while away from Borneo. Ernest Hose has long lived at Diss, Norfolk, England, where he has continued an active correspondent until recently.

3. For clarity, we may repeat that the Harrisson reference here is to the 1949 study previously cited among the twelve base references printed after the Preface; these are given here and hereafter *without* any year-date following author's name.

4. H. H. Everett and John Hewitt in *J.S.B.A.S.*, 51, 1909: 1-30, the previous text on Santubong, more fully referred to in our Chapter III.3. (*J.S.B.A.S.* was the predecessor of *J.M.B.R.A.S.*; see Preface).

5. Courtesy Dr. J. R. Dunsmore and his colleagues in Kuching, who have been most helpful.

Chapter 2. Systematic Excavations, 1947-66

1. "Indian" gold and related objects not earlier discussed in Harrisson's 1949 survey are dealt with further in our Chapters 26-32 of Part V in this Data Paper.

2. To Dr. John Pope, then, this and other island projects must owe a special debt of thanks. His unusual foresight in evaluating the "export" aspects of mainland ceramic and other cultures has had a large effect in overcoming a previous tendency to consider only the "imperial" and mainland streams through Southeast Asia after 700 A.D. See also Chapter II.12, Note 8.

3. Other trench data are given as necessary in main text. Mention should also be made here of the sector of the 1955 Buah excavations often used for *deep* slag and related conditions (e.g., ceramic scatter) at Buah, unless otherwise stated:

Trench	Surface area (sq. feet)
D	1,194
E and F	85
H	208
J and M	81
	1,568

Chapter 3. Key Sites and Mobility

1. These three brief descriptions of the sites are orientated towards their relevance to iron-working and are *not* intended to give a comprehensive, complete idea for all archaeological points of view at this stage.

2. *Trans. Oriental Ceramic Soc.*, London, 1954: 1-12 (with Color Plate and other illustrations of early Jaong ceramics).

3. See Chapter 1, Note 1. For the photos referred to in (c) following in the text, the director of Lands and Surveys, Mr. Eric Lawrence, C.B.E., gave generous assistance. This included putting an air-survey aircraft on charter at our disposal for special and close-up flights of all the delta sites.

4. Compare Chapters II.12 and V.32 following on such "immediate" factors.

5. The Kubor cemetery is the only delta site so far reported separately, in two principal papers: T. and B. Harrisson, "The Prehistoric Cemetery at Tanjong Kubor," *S.M.J.*, 8, 1957: 18-50; and W. G. Solheim, 13, 1965; 1-62 (cf. Chapter III.16, Note 4).

6. See further in Chapters IV.24 and VI.36.

Chapter 4. Time Sequence in the Delta

1. Carla Zainie with Tom Harrisson, "Early Chinese Stonewares excavated in Sarawak, 1947-1967: a suggested first basic classification," *S.M.J.*, 15, 1967: 31-89, which is fully illustrated with photographs and line drawings.

2. Chinese coins are best identified with Fredrik Schjothts *Chinese Currency;* revised from Oslo edition (by V. Hancock); Iola, Wisconsin, 1965. See also parallel series of coins from Brunei excavations in *S.M.J.*, 8, 1958: 1-40.

3. On the Gupta buddha from the delta see A. B. Griswold in *S.M.J.*, 10, 1962: 363-371, and in a ceramic context S. J. O'Connor, 12, 1964: 565-567.

4. It must be emphasized that this is not a complete or even a preliminary overall report on the delta excavations; but simply on special aspects of the iron industry there. Full results will require much more comprehensive treatment in due course, as indicated in Appendix 1.

Part II. The Evidence of Iron Slag

Chapter 5. The Slag in Local Belief and Prehistoric Fact

1. In Chapters III.19 and VI.33-36.

Chapter 6. Scale of Delta Iron Deposits: A Broad View

1. Mr. Chen Boon Kong was trained at the Institute of Archaeology, London University. For personal reasons he left Sarawak Government (Museum) service in 1954 and went to live in Singapore, where he has become a successful businessman--and a loss to prehistoryt

2. Batu Gambar is important to the delta sites in the wider context. It is further discussed in Chapter V.32, and illustrated as our Frontispiece, Plate 1.

Chapter 7. Slag Measurement Standards

1. Special thanks are due to Lt. B. P. Holloway and Sergeant E. Sayers, Royal Engineers, seconded from FARELF, Singapore, who conducted this training under uncomfortable swamp conditions.

2. CBK here and elsewhere refers to Mr. Chen Boon Kong as at Chapter 6, Note 1.

Chapter 8. Some Quantitative Slag Results

1. No really impressive *heaps* of this kind have been reported in Southeast Asia, to the best of our belief. Nothing comparable, say, to those at Mt. Meru (Meroe) in Africa (see Chapter VI.35). This absence *may* in itself be significant of different iron-working processes. It would seem difficult to produce a solid slag "mountain effect" by the open-hearth method which we postulate as normal in the Sarawak River delta (cf. Chapters II.10 and III.19). See also the considerations raised in Appendix E (M.I.T. Seminar). We are now pursuing the quantitative side with the help of some of the metallurgists mentioned. But mass alone is an inadequate index; the quality of the product--which we have suggested as good--is also clearly as important as the at least 20,000,000 lbs. of finished metal indicated at page 53 of this Chapter, using a crude 4 slag to 1 finished metal guess.

Chapter 9. A Morphological Analysis of Slag

1. The District Officer, Kuching, Wan Ali bin Tuanku Ibrahim, kindly granted these and other facilities.

2. L. Linehan, "Traces of a Bronze Age culture associated with Iron Age implements in the regions of Klang and the Tembeling, Malaya," *J.M.B.R.A.S.*, 3, 1951: 12-16 and Fig. 10; and M. W. F. Tweedie, "The Stone Age in Malaya," *J.M.B.R.A.S.*, 26, 1953: 1-90.

3. This may be a useful consideration in further studies elsewhere?

Chapter 10. What Do Slag Forms and Numbers Mean in Terms of Process?

1. T. and B. Harrisson, first excavation of Kota Batu, the ancient capital of Brunei, as described in *S.J.M.*, 7, 1958: 283-319.

2. V. B. Proudfoot in *Science Journal*, 3, 1967: 60.

3. See further in detail in Chapter VI.34.

4. The full passage and reference for Dr. Chibbher's valuable work are in our Chapter VI.33.b following; see also Chapter VI.34.b on different *furnace* systems.

5. Spenser St. John, *Life in the Forests of the Far East*, London, 1863, Vol. I: 122; one of the very best books about Borneo, by a pioneer explorer of the western interior.

6. Questions of fuel, air supply, ore content, flux, etc., are considered specifically in Chapters III.13, 16, 18, and IV.21, 25; also slag chemistry in IV.22.

Chapter 11. Slag Scatter Patterns

1. As detailed previously in Chapter II.8.i, here defining "scatter" at less than 1 lb. of slag per surface square foot; cf. also page 49 of main text.

Chapter 12. The Magic Iron

1. G. W. Earl, *The Eastern Seas*, London, 1837: 263. This book is most useful on southern Borneo.

2. I. H. N. Evans, *The Religion of the Tempasuk Dusuns*, Cambridge, 1953, the only major source for Sabah (North Borneo) folklore. All page references in the following paragraph of the main text refer to this volume.

3. The Iban material, chant texts and genealogies here used are all from T. Harrisson and B. Sandin, "Borneo Writing Boards," in *S.M.J.* Special Monograph, no. 1 of 1966: 32-286. Compare also Benedict Sandin, *The Sea Dayaks of Borneo before Brooke Rule*, London, 1968. Mr. Sandin, now Curator of the Sarawak Museum, has also written many papers on Iban folklore in regular volumes of *S.M.J.* and as separate books (in Iban) published by the Borneo Literature Bureau, Kuching, Sarawak. He read and approved this Chapter in draft while visiting Cornell in September 1968. And see Note 10 below.

4. Joseph Needham's *Science and Civilisation in China*, Cambridge, 1962, Vol. IV, Part 1: 250. See also Needham's special study of Chinese iron technology in the twelve basic texts listed after the Preface.

5. E. D. Baumann, *De mythe van den Manken God*, Amsterdam (no date); cf. the splendid Chapter IV in R. J. Forbes, entitled "The Smith, his Social and Sacred Status." Also examples of similar situations in the Philippines, India, Africa, and elsewhere cited in Part VI of our text, Vol. II.

6. Claire Holt, *Art in Indonesia,* Ithaca (Cornell University Press), 1967: 276; a stimulating new approach to this theme. Compare also Chapter VI.33.b following.

7. David Sopher (Professor of Geography at Syracuse University), *Geography of Religions,* New York, 1967: 40. His earlier *The Sea Nomads,* Singapore (National Museum), 1965 is also relevant to this study, dealing fully with the maritime Bajau peoples of the South China Sea, for whom we postulate a significant role as carriers in the prehistoric iron trade (Chapter IV.24, etc.).

8. See on this sherd usage Barbara and Tom Harrisson in *J.M.B.R.A.S.*, 46, 1968: 148-175. A full study of the early stoneware jars is in preparation as one of several contributions to a volume reporting the findings of the 1968 Manila Seminar on Trade Pottery, organized by Dr. John Pope and Dr. R. Fox, to be published through the Smithsonian Institution in 1969.

9. These aspects of slag distribution are touched on further at Chapters V.32, 30, 31, and 28 respectively; and the "phallic tops" at III.10.

10. No mention has been made in this Chapter of another very important *lame* person in the high pantheon of Sea Dayak theology, Simpang Impang alias Patang Raga, a mighty ghost whose mother (Dayang Racha) is made pregnant by pieces of rubbed-wood sparking--so that he is born with only one good one of everything (and thus lame). His "true father" was Bunsu Api, "Great Fire," who provides the flame of the smith's bellows, which Bunsu Ribut fans (as equally for Selempandai's hill-hole; see main text). See further at Chapter III.19, also Note 3 above.

Part III. The Evidence in Clay

Chapter 13. "Crucible" and Slag

1. For other earthenware forms see Chapter III.16.

2. H. H. Everett and John Hewitt, *J.S.B.A.S.*, 51, 1909: 10; cf. Chapter I.1, Note 4. An earlier reference to stray finds in Santubong is in the *Sarawak Gazette,* 1888; 87, which refers however to crucible there as of "stone." Note in the passage quoted reference to "contents of the crucible are iron slag."

3. Cf. Chapter III.15.

4. In Chapter VI.36.

5. *Our* italics in the Hose text (see Twelve Basic References) which is more fully quoted in VI.36.c. See also the accounts there cited for the Sarawak Kayans from Burns and in Appendix B the Schwaner account from Kalimantan.

6. Full measurements are in Chapter III.15.

7. We have also larger but well tapered tuyères from the Philippines (Chapter VI.33.c) which to some extent support the possibility that crucible and tuyère may have been regarded as the "same sort of thing" technically--and especially by the potter--at one time (the smelting time) in this part of the world. Some very large cylindrical tuyères are used with skin bellows in parts of Africa (Chapter VI.35). See also Appendix E.

8. J.M. Heath, "On Indian Iron and Steel" in *Journ. Royal Asiatic Soc.*, 5, 1839: 390-393; cf. Chapter VI.34, Note 24.

9. Heath was later confirmed by Holland as detailed in M. S. Krishnan, *Iron Ores of India*, Calcutta, 1955: 40-45, a very useful work which also summarizes other relevant information, including on earthenware "air-pipes from Madhya Pradesh"; see further at VI.34.a.

10. See also the role of green bamboo in this, at Chapter III.17 following; and further reference in main text below (Keppel, Mundy).

11. H. Keppel, *The Expedition to Borneo of H.M.S. Dido*, London, 1846, Vol. I: 65.

12. R. Mundy, *Borneo and Celebes*, London, 1848, Vol. II: 65.

13. T. Harrisson, "Outside Influences on the culture of the Kelabits of North Central Borneo" in *Journ. Polynesian Soc.*, 3, 1949: 91-111; and *S.M.J.*, 6, 1950: 104-125.

14. Cheng Te-K'un, *Archaeology in China*, Cambridge, Vol. III; *Chou China*, 1963: 246. See also "Twelve Basic Reference" list in our Preface.

Chapter 14. Crucible Quantities and Associations

1. Weight details in Chapter III.15.g (also Appendix E).

2. If the cylinders were partly, alternatively, or wholly in tuyère use, the number of forge-days might have been much higher.

Chapter 15. Crucible Shapes and Sizes

1. Ananda Coomaraswamy, *Mediaeval Sinhalese Art*, New York, 1950: 192; a major work in its class.

2. For further discussion and a possible technique very interestingly paralleled as a special pottery method see Chapter III.16.g; also the role of bamboo in this at Chapter III.17.d.

3. This estimate related to delta gross total figures given earlier at Chapter III.14.i; as also in following section h of this chapter.

4. After this Data Paper was completed its main content was put forward at Professor Cyril Stanley Smith's Seminar at M.I.T., Boston, 13 November 1968, with a view to proceeding a stage further in the direction of seeking more metallurgic and laboratory examination of the delta materials. (Compare our ideas as stated in the Preface with Appendix E.)

5. We return to encrustation and blocking at Chapter III.19 below, and in other connections at V.27.

Chapter 16. Related Pot Forms

1. D. Freeman on Iban potting in *S.M.J.*, 8, 1957: 153-173.

2. T. Harrisson and M. W. F. Tweedie on the Bau cave excavations at the headwaters of the Sarawak River, in *Journ. Polynesian Soc.*, 60, 1951: 164.

3. Named from the material excavated at Bau as in Note 2 above. See W. G. Solheim in *Proc. Ninth Pacific Science Congress*, 3, 1964: 30, and many subsequent papers; cf. Note 4 below.

4. W. G. Solheim, "Prehistoric Earthenwares of Tanjong Kubor," *S.M.J.*, 13, 1965: 1-62; for the related general Kubor paper see Chapter I.3, Note 5.

5. D. Sopher, *The Sea Nomads*, Singapore, 1964 (cf. Chapter II.12, Note 7).

6. This carrier role is further discussed in later chapters.

7. Compare I. H. N. Evans, "Bajau Pottery," *S.M.J.*, 6, 1955: 297-300.

8. To (1) in Dr. Cheng's notes in the text may be added the very full survey of *tsu* by Bernard Karlgren, in which he proposed neolithic origins and relates the class as a whole to "phallic emblems" from Mahenjo-daro and the Indus civilization (*B.M.F.E.A.*, 14, 1942: 65-69; his Plate I is close to some prehistoric artifacts from Luzon, see below). William Watson's *China before the Han Dynasty* illustrates the phallus = ancestor character on Shang oracle bones in a very "Santubong" form (London, 1961: 181, fig. 26).

9. Dr. Solheim as at Note 4 above.

10. Rosa C. P. Tenazas (ed.), *A Report on the Archaeology of the Locsin-University of San Carlos Excavations in Pila, Laguna*, with Introduction by Leonardo and Cecilia Locsin, Manila, 1968. This is only one of several ongoing archaeological projects in the Philippines at this time (see also Appendix F).

11. T.H. in Manila, March 1968 and January-February 1969.

12. As Note 10, at her p. 22.

13. As above, p. 8; this version of the text is based on a local study in *Philippine Social Sciences and Humanities Review*, 24, 1959: 92-94; the wording is slightly different in Hirth and Rockhill's well-known translation, St. Petersburg, 1911: 156, part of which is also cited at the start of Part I to the present Data Paper.

14. For Kuala Selinsing see further in Chapter VI.33.

15. Compare the lead "ear-ring" from Buah at Chapter V.29.b.

16. *S.M.J.*, 12, 1965: 1-62.

17. H. F. Tillema, *Apo-Kajan*, Amsterdam (no date); 190-191, and Figs. 146-148. See also Chapter VI.37 on Kayan-Kenyah damascene, etc. The Dutch *j* equals the English *y*, of course.

18. Solheim in *Journ. Siam Soc.*, 52, 1964: 151-161 for N.E. Thailand; *idem* 54, 1967: 81-84, Plate IA for the Luang Probang bamboo cylinder method; also noted there by T.H. in 1953 (large pot-community near airfield).

19. Homo Sasoon on the Sukur smelting in *Man*, 64, 1964: 215.

20. Information on the Marghi (close to the Sukur) from Dr. James Vaughan Jr., Indiana University, personal communication to T.H. October 4, 1968, cf. his forthcoming full account to be published by Indiana University Press, Bloomington. Also Brian Fagan, *Iron Age Cultures in Zambia*, London, 1967, Vol. I: 88. And at VI.35 below. (Dr. Fagan is further cited in Appendix E, 5.)

Chapter 17. Bamboo

1. A. R. Wallace, *The Malay Archipelago*, London, 1869: 61 (now available in Doverbooks Facsimile Paperback editions); see also our quotation on Title Sheet on this Volume One.

2. Cf. earlier at Chapter III.14.d, and further at VI.36 and in Appendix B (Schwaner).

3. Paul Wheatley, *The Golden Khersonese;* Kuala Lumpur (university of Malaya), 1961: 224 in general an admirable work.

4. *Encyclopedia Britannica*, 1968 ed., vol. 3, "Bamboo."

5. T. Harrisson, *The Malays of Southwest Sarawak Before Malaysia*, London, 1969: Chapter F.9.

6. Wallace (as 1 above); 59.

7. T.H. personal observation and film (available at Cornell).

8. The oldest trees, like the oldest bamboo clumps, could overlap the end of the Bongkisam operations narrowly in time. See also bamboo in Madagascar, at Chapter IV.35 (end).

Chapter 18. Charcoal and Other Fuel Factors

1. Compare J. U. Nef, *The Rise of the British Coal Industry*, London, 1966; and R. Schubert, *The History of British Iron and Steel Technology*, London, 1957.

2. J. G. Watson in *Malayan Forest Records*, 6, 1928; I. H. Burkhill, *A Dictionary of Economic Products of the Malay Peninsula*, London, 1935, Vol. I: 1888, who comments on mangrove.

3. F. G. Browne, *Forest Trees of Sarawak and Brunei*, Kuching, 1955: 298-300, who deals with these and other charcoalable woods in some detail (pp. 64, 74-75, 181, 191, 271, 298-300, 360).

4. For a full study of modern mangrove and charcoal, now almost a Chinese monopoly in the Delta, see T.H. book on the Malays, 1969 (Chapter I, Note 1). James L. Cobban's recent useful study *The traditional Use of the Forests in Mainland Southeast Asia* (Ohio University, Center for International Studies; Athens, Ohio, 1968) sometimes underestimates the importance of pre-recent forest usage, especially for Malayan mangrove swamps (pp. 15-18), which were certainly exploited at Kuala Selinsing, for instance, contemporaneously with Santubong (cf. our Chapter VI.36.b, etc.).

5. V. B. Proudfoot, *Science Journal*, 3, 1967: 61; see also Borneo ethnological data in Chapter VI.36 following.

6. The whole delta ecology, especially the mangrove swamp sections between the Santubong and Bako branches of the Sarawak River, were put under a radically new kind of notice recently when Tengku Abdul Rahman, Malaysia's Prime Minister, proposed a huge new padi-cultivation scheme. This unexpected revaluation of a previously somewhat unappetizing area for agriculture has not, as yet, been supported by soil and swamps, which initially indicate a high sulphur content and acidity, giving low fertility and poor potential crop yields (see a careful report from P. C. Shivadas of Kuching in *Straits Times*, 6 December 1969, which comes as no surprise to those who have dug in this area for archaeological reasons).

Chapter 19. How Was the Crucible Used and for What?

1. See N. Barnard, *Bronze Casting and Bronze Age Alloys in Ancient China*, Tokyo, 1961: Plate 8, to supplement Needham's excellent iron-crucible Plates 11-13; also our Chapter VI.34.b on Chinese crucibles.

2. Selampandai, cf. Chapter III.12.b; also V.29.b relates, as also Note 10 for II.12 above. Here again we are indebted to Mr. Benedict Sandin for help with Sea Dayak (Iban) texts.

3. On possible Ragvedic Age parallels see M. N. Banerjee's various articles, e.g., in *Indian Historical Quarterly*, 5, 1929: 432-440 and 8, 1932: 364-366.

4. Paul Wheatley, "Commodities involved in the Sung Maritime Trade," *J.M.B.R.A.S.*, 32, 1961: 7-143.

Part IV. Mineralogical Evidence

Chapter 20. Ore Supplies and the Delta Industry

1. Compare Chapter IV.24 following. But it is not untypical that one of the early monographs for the island, Theodor Posewitz's *Borneo*, Berlin, 1889 (in German) devotes 52 pages to gold, 31 to coal, 22 to diamonds, 6 to iron.

2. Posewitz (as above): 331 gives 68% iron content for magnetite ore from Southeast Borneo; he describes the stone hammers as of "greenstone" (332). "Wootz" and Magnetite are further discussed in Chapter VI.34.

3. For "open hearth," see Chapter II.10. Information on ore porosity and other points here from Dr. Anthony Pimm for the Geological Survey, acting as our advisor in 1966, as did Dr. G. E. Wilford and other able geologists in previous years.

4. The Kenyahs on the Tinjar tributary of the Baram River in northern Sarawak may have been using this or a related riverine ore in 1932, according to unpublished observation on the Oxford University Expedition of that year (T.H.).

5. The iron ore called haematite is described in full use in the stone age at Niah in various *S.M.J.* papers, as well as in *Man* 59, 1959: 1-9 (with Color Plate of haematite paintings). The same usage is common in West Malaysia; see M. W. F. Tweedie, "The Stone Age in Malaya," *J.M.B.R.A.S.*, 26, 1953: 1-90.

6. An interesting recent study of Malaysian laterites is R. J. Eyles in *Journ. Tropical Geography* (University of Malaya), 25, 1967: 18-23.

7. For an excellent account of roasting before smelting see Tylecote: 189. Also Schwaner's account for Kalimantan in our Appendix B.

8. Other references to ores are in Chapter VI.36-37, including the possible nineteenth century use of *meteoric* iron in the Barem River Basin (Hose, St. John) though this requires technical conformation. Also for that area of northern Sarawak, Burns described 70% ore-iron productivity among the Kayans over a century ago (Chapter VI.36).

Chapter 21. Ore Analyses

1. From the mouth of the Samarahan to the eastern mouth of the Sarawak River (at Muara Tebas) is 2-4 hours fair weather sailing inside the partial shelter of the bay.

2. Compare Chapters V.29 and VI.36 on other mining records for this upriver area. See also Iron Pyrites, Appendix F.

Chapter 22. Slag Analyses and Some Comparisons

1. H. H. Everett and J. Hewitt in *J.S.B.A.S.e*, 51, 1909: 12 (cf. Chapter I.1, Note 4).

2. Information from Overseas Geological Survey courtesy Dr. A. C. Pimm, July 4, 1966.

3. This "Sung-Yuan" term relates to the associated ceramics used in dating as explained in Chapter I.4 and further examined in Chapter V.31.b. It is not meant to imply any necessary connection with Chinese periods directly; these ran from 960-1279 and 1280-1368 A.D.

Chapter 23. A Philippine Slag Comparison

1. Robert Fox, "Excavations at Calatagan," *Philippine Studies*, 7, 1959: 321-390. Much of the Philippine work, like that for Borneo, remains to be published. See also Chapter III.16, Note 10.

2. And see Chapter IV.22.

3. At this time, it had been suggested by a distinguished archaeologist that the delta slag *could* not represent an iron industry and might be a gold working residue.

4. We shall see that there are significant parallels between *northern* Philippines and Bornean iron-working in historical times, whatever the past. See Chapter V.28 on "waisted stones" especially, and generally Chapter VI.33.c; cf. VI.37.

5. New work on Philippine slags has recently been carried out by Dr. Karl Hutterer, working from San Carlos University, on Cebu, which we hope to include here as Appendix F if received in time for Volume Two (cf. Appendix E.5).

Chapter 24. Some Island Logistic Problems

1. Paul Wheatley, *J.M.B.R.A.S.*, 32, 1961: 1-140 (cf. Chapter II.19, Note 4).

2. As 1 above: 77.

3. As 1 above: 117.

4. R. Hartwell's two papers are in *Journ. Asian Studies*, 21, 1962: 153-162; and *Journ. Economic History*, 26, 1966: 29. The paragraph quoted is from the latter. See also John V. Nef, *Cultural Foundations of Industrial Civilisation*, Cambridge (Eng.), 1958: 56-62.

5. Our italics in Needham: 48 extractt See also Part VI further (especially Chapter VI.33, first paragraph).

6. F. R. Tegengren, "The Iron Ores and Iron Industry of China," Part II, *Memoirs of the Geological Survey of China*, Series A, 2, 1923t

7. The modern "geology" of West Borneo was in its infancy when the Geological Survey was started conjointly for Sarawak and Sabah, then separate Crown Colonies (now the two constituent states of East Malaysia) from 1946.

8. Cf. also Stamford Raffles on inter-island iron traffic continuing after 1800 A.D., discussed in Chapter VI.37.

Chapter 25. The Question of Flux

1. H. H. Everett and J. Hewitt in *J.S.B.A.S.*, 51, 1909t 12.

2. Flux possibilities are referred to further in Appendix E.6; also Appendix F.